GROUNDWATER QUALITY ASSESSMENT PLAN PHASE 2

General Motors Corporation-Fisher Guide Division

Elyria, Ohio

May 1987

WESTON

MANAGERS   DESIGNERS/CONSULTANTS

GROUNDWATER QUALITY ASSESSMENT PLAN
PHASE 2

GENERAL MOTORS CORPORATION -FISHER GUIDE DIVISION

Elyria, Ohio

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SECTION 1

INTRODUCTION

The General Motors Corporation (GMC) Fisher Guide Division facility is located in Lorain County, Elyria, Ohio, approximately 25 miles southwest of Cleveland. The facility formerly operated a waste management area consisting of three adjacent sludge surface impoundments (Figure 1-1). Sludges placed into the impoundments were from plant processes which have included chrome electro-plating operations classifying the sludges as F006 (for a discussion of sludge characteristics refer to Section 1.1.1). No plant process sludges have been placed into the impoundments since September, 1986.

In 1981, a monitor well network consisting of six wells was installed around the impoundments to fulfill the Resource Conservation and Recovery Act (RCRA) requirements under O.A.C. 3745-65-93(D)(1) and 40 CFR Part 265, Subpart F. Four wells were subsequently sampled on a quarterly basis for one year, the water samples being analyzed for parameters defined under RCRA Part 265.92 (2) and (3) to establish a background data base. Subsequent semi-annual sampling results were compared to the established background level for each well. Statistically significant differences for various wells were noted for the indicator parameters pH, specific conductivity, and total organic carbon (TOC). Indicator parameter data are included in Attachment 1.

In accordance with RCRA requirements under O.A.C. 3745-65-93(D)(4)(a) and 40 CFR Part 265.90, GMC contracted Groundwater Technology, Inc. to develop a Groundwater Quality Assessment Plan (GWQAP) to determine the following:

- o   Whether hazardous waste or hazardous waste constituents have entered the groundwater.

- o   The rate and extent of migration of hazardous waste or hazardous waste constituents in the groundwater.

- o   The concentrations of hazardous waste or hazardous waste constituents in the groundwater.

The Groundwater Technologies, Inc. investigation suggested that various non-RCRA constituents (i.e., chloride, sulfate) were migrating from the impoundments into the groundwater system. In addition, there were volatile organic compounds (VOC) detected in one downgradient well (P-5), however, the source of the VOC's could not be determined to be the surface impoundments as this well is located immediately east of a pad previously used for dye storage. Also noted in the study were statistically significant increases in indicator parameters for various downgradient wells.

FIGURE 1-1 SITE MAP

Legend:
- A———A' CROSS-SECTION LINE
- ● EXISTING MONITOR WELL

Scale in Feet
0   400

-N-

MANUFACTURING BUILDING

OFFICE

SLUDGE FILTER BASINS

P-6
P-4
C'
OW-1
B
P-5
C
A
P-1
B'
P-2
A'
P-3

PENN CENTRAL RAILROAD

LOWELL STREET

WESTON
ROY F. WESTON, INC.
DESIGNERS CONSULTANTS
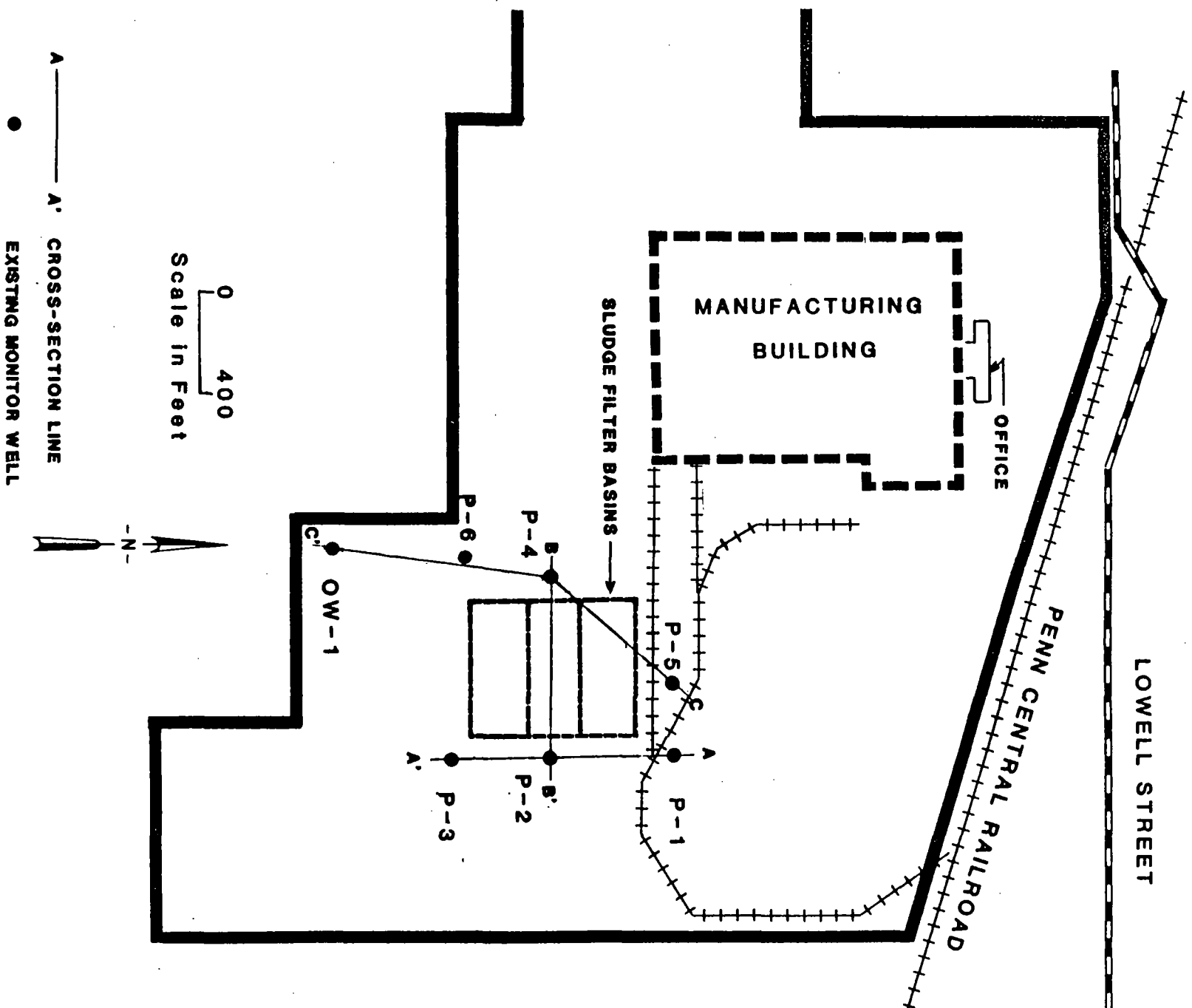
1-2

Continued groundwater monitoring since the initial investigation has shown the presence of VOC's only in monitor well P-5 and statistically significant changes in indicator parameters for other downgradient monitor wells. Based on this data, the Ohio Environmental Protection Agency (EPA) has required a second phase groundwater quality assessment to be performed pursuant to Ohio regulations OAC 3745-65-91 through 94. The principal objectives of the second phase of the assessment are to:

o   Determine if there has been an excursion of hazardous waste or hazardous waste constituents from the impoundments to groundwater.

o   If necesary, further define and quantify any hazardous constituent plume originating from the sludge surface impoundments.

o   Assess the impact of any contaminant plume on local groundwater quality.

o   Investigate any potential upgradient sources of ionic contamination (the new upgradient well, OW-1, showed elevated levels of chloride).

o   Determine if the volatile organic compounds detected in monitor well P-5 are originating from the impoundments.

This Groundwater Quality Assessment Plan (GWQAP) is more comprehensive than the requirements established under 40 CFR 265.91 and has been developed after extensive consultation with the Ohio Environmental Protection Agency to satisfy state concerns as well as to fulfill the objectives stated above. State and federal regulations and the RCRA Groundwater Monitoring Technical Enforcement Guidance Document (September, 1986) have been used as guides in developing the approach and strategy for this program to comply with state and federal regulations.

1.1   BACKGROUND DATA

1.1.1   Sludge Waste Characteristics

The sludges in the three impoundments originated from plant processes which included copper, nickel and chrome electroplating operations. The sludges have been classified as an EPA hazardous waste F006. In 1982 a partial waste characterization of surface impoundment sludges was performed. The impoundments were divided into quadrants. A sample was collected from each quadrant and analyzed for RCRA parameters to determine mobile constituents and document its status as a hazardous material. The sludges were found to be non-hazardous with respect to pH, flash point, corrosivity, and reactivity. Analyses of various total metals are

TABLE 1-1

SUMMARY OF AVERAGE TOTAL AND EP-TOXICITY
METALS DATA FOR SURFACE IMPOUNDMENT SLUDGES

Total Metals (mg/kg)	Basin 1	Basin 2	Basin 3	U.S. EPA EP-Toxicity Guidelines
Nickel	6000	7125	2850	NA
Cadmium	<2	<2	<2	NA
Chromium	23,550	26,075	11,700	NA
Hexavalent Chromium	9.07	3.33	0.54	NA
Lead	46	144	37	NA
Copper	3500	5640	3630	NA
Zinc	2660	1780	1200	NA
Iron	3400	3220	1260	NA
EP-Toxicity Metals (mg/l)				
Arsenic	<0.001	<0.001	<0.001	5.0
Barium	<0.05	<0.06	<0.05	100
Cadmium	<0.02	<0.02	<0.02	1.0
Chromium	4.1	9.0	10.3	5.0
Lead	<0.11	<0.082	<0.082	5.0
Mercury	<0.001	<0.007	<0.002	0.2
Nickel	11.8	24.0	8.4	NE
Selenium	<0.001	<0.001	<0.001	1.0
Silver	0.03	0.03	0.1	5.0

NA - Not applicable

NE - Not established

Note: All analyses performed by Chester Laboratories. Samples were collected on 6/24/82.
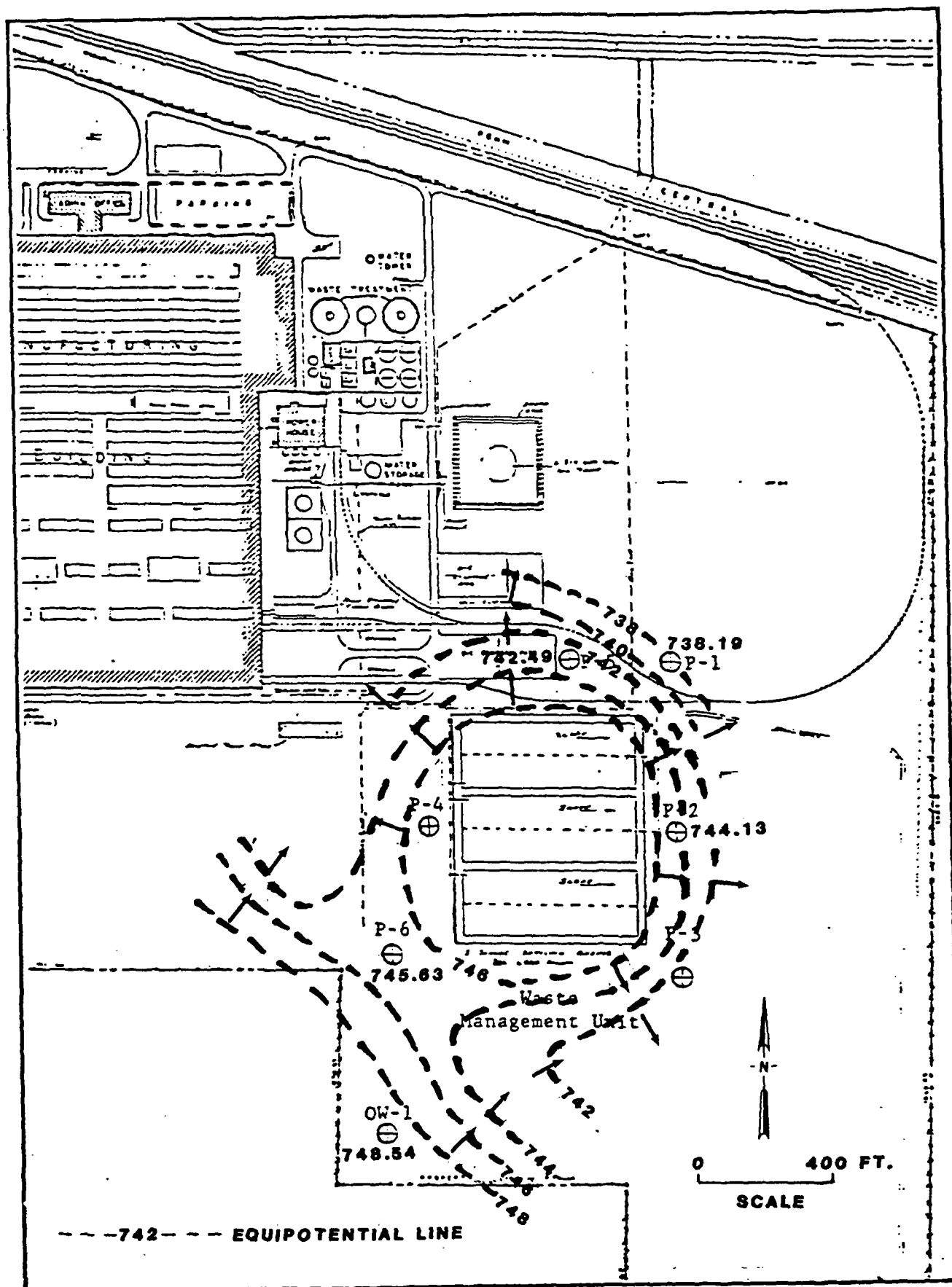
presented in Table 1-1. The results show nickel, chromium, copper and zinc in the largest concentrations, with only a small fraction of the total chromium consisting of the hexavalent ion. A summary of the EP-Toxicity analyses is also presented in Table 1-1. A review of the data shows chromium to be the only mobile metal which exceeds U.S. EPA EP Toxicity standards. The sludges are therefore considered to be hazardous with respect to U.S. EPA EP-Toxicity metals criteria for chrome. No data is presently available with respect to the potential volatile organic fraction within the sludges.

1.1.2 Geology/Hydrogeology

Based on boring logs of existing on-site monitor wells the geology in the vicinity of the GMC-Fisher Guide facility, pertinent to the GWQAP, can be divided into four stratigraphic units. The locations of existing monitor wells and geologic cross-sections developed from the well logs are presented in Figures 1-1 and 1-2, respectively.

The uppermost unit consists of soft, light brown to greenish gray silty clay till deposited during the Wisconsinan glacial advance approximately 10,000 years ago. This unit generally ranges in thickness from 8 to 12 feet below the site. Underlying the till deposits is the Orangeville Shale which consists of soft light greenish gray shale. This unit is absent under most of the site, however, it has been identified in borings from the southeast portion of the site. Its maximum thickness under the southeast portion of the site is approximately five feet. The Berea Sandstone underlays the glacial drift or Orangeville Shale (depending on whether or not the shale unit is present) and is considered the uppermost aquifer. The Berea Sandstone is generally described as a hard, fine grained sandstone with occasional very thin shale interbeds. The existing water table is located within this unit and the overlying glacial till. In the area of the surface impoundments, the sandstone is a wedge-shaped aquifer which thickens to the northwest from approximately 5 to 23 feet. Underlying the Berea Sandstone is the Bedford Shale. It is generally described as a gray to reddish silty shale with some thin sandy horizons. The on-site borings have not penetrated the entire thickness of the Bedford Shale however background information indicates that the unit averages from 50- to 90- feet thick. On-site borings which penetrate the Bedford Shale indicate that no mappable sandy horizons exist within the shale for at least 10 feet below the Berea Sandstone.

One constant head test and a series of slug tests were conducted by Groundwater Technology, Inc. on monitor wells screened within the Berea Sandstone. Permeabilities were found to range from 3.1×10^{-4} cm/sec to 12.5×10^{-4} cm/sec. Based on these permeabilities a representative permeability

1-5

WESTON

742.49 ⊕ P-3

738.19
⊕ P-1

740

738

P-4 ⊕

P-2
⊕ 744.13

P-6 ⊕
745.63

746

P-5 ⊕

Waste
Management Unit

742

OW-1 ⊕
748.54

744

746

748

-N-

0   400 FT.

SCALE

– – –742– – – EQUIPOTENTIAL LINE

FIGURE 1-3   GROUNDWATER CONTOUR MAP
BASED ON READINGS OBTAINED IN
NOVEMBER, 1986

of 7×10^{-4} cm/sec (1.98 ft/day) was estimated for the Berea Sandstone.

Groundwater elevations obtained from the on-site monitor wells in November, 1986 were used to determine existing groundwater flow directions at the site (Figure 1-3). The groundwater contour map confirms the previous interpretations showing a groundwater mound beneath the surface impoundments with groundwater flowing radially away from the impoundments. However, based on background data regional groundwater flow is to the northeast. An average horizontal flow gradient of 0.018 ft/ft is estimated in the vicinity of the groundwater mound.

1.1.3 Existing Monitoring Well Network

A total of seven wells have been installed around the surface impoundments to monitor upgradient and downgradient water quality. The areal and stratigraphic locations of the wells are shown in Figures 1-1 and 1-2. Well P-4 was destroyed by vehicular traffic and has since been properly closed.

The current monitoring network design is focused at detecting potential contaminant migration along the base of the Berea Sandstone. The wells are constructed of 2-inch inner diameter (I.D.) PVC with glued joints. All screens are five-feet long. A gravel pack extends from the base of the well screen to approximately one foot above the top of the screen. One foot of sand was placed above the gravel pack and the remainder of the annular space backfilled with a bentonite slurry. Protective steel casings were placed over the PVC risers at the surface.

1.1.4 Existing Water Quality Data

Water quality data has been collected for most on-site wells (except OW-1 which is a new upgradient well installed in December, 1985) since January, 1982. The initial groundwater quality assessment performed by Groundwater Technologies, Inc. in conjunction with the groundwater data generated since the study indicates that:

o   Certain non-hazardous constituents (i.e., chloride, sulfate) appear to be entering the groundwater from the impoundments and a plume can be roughly defined.

o   Heavy metals associated with the source sludges have not exceeded any drinking water standards and do not appear to be a problem.

o   Volatile organic compounds were detected only in monitor well P-5.

1-8

TABLE 1-2

SUMMARY OF SELECTED* PARAMETERS FROM 1985-1986 GROUNDWATER QUALITY DATA

Parameter	Date Sampled	Monitor Well Number P-1	P-2	P-5	P-6	OW-1
Chloride (mg/l)	11/12/86	42	22	146	13.0	10.0
	9/06/86	82	24	146	6.0	8.0
	6/17/86	68	24	142	3.0	12
	4/08/86	76	23	139	4.0	10
	12/19/85	41	29	110	4.0	--
	9/12/85	140	25	41	4.0	--
	6/28/85	120	2.6	0.88	2.6	--
Sulfate (mg/l)	11/12/86	293	178	275	157	39
	9/06/86	322	200	291	204	36
	6/17/86	371	225	389	146	57
	4/08/86	425	246	334	174	109
	12/19/85	310	180	270	200	--
	9/25/85	29	150	320	88	--
	6/28/85	221	199	288	140	--
Magnesium (mg/l)	11/12/86	53	28	41	31	18
	9/06/86	60	33	42	42	18
	6/17/86	124	64	76	87	66
	4/08/86	53	27	33	32	24
	12/19/85	50	22	32	34	--
	9/25/85	22	27	62	47	--
	6/28/85	40	36	47	43	--
Sodium (mg/l)	11/12/86	68	96	95	6	23
	9/06/86	74	84	80	10	20
	6/17/86	78	112	100	14	34
	4/08/86	82	87	87	5	22
	12/19/85	6.9	78	86	7.5	--
	9/29/85	99	90	56	14	--
Chromium (mg/l)	11/12/86	<0.01	<0.01	<0.01	<0.01	<0.01
	9/06/86	<0.01	<0.01	<0.01	<0.01	<0.01
	6/17/86	<0.01	<0.01	<0.01	<0.01	<0.01
	4/08/86	<0.01	<0.01	<0.01	<0.01	<0.01
Iron (mg/l)	11/12/86	0.56	0.23	0.27	0.28	0.29
	9/06/86	0.30	0.12	0.23	0.08	0.18
	6/17/86	0.12	0.13	0.46	0.17	0.50
	4/08/86	0.47	0.22	0.18	0.15	0.98
1,2 Trans-Dichloroethylene (ug/l)	11/12/86	ND	ND	ND	ND	ND
	9/06/86	ND	ND	ND	ND	ND
	6/17/86	ND	ND	ND	ND	ND
	4/08/86	<5	<5	267	<5	<5
Trichloreothylene (ug/l)	11/12/86	<5	<5	261	<5	<5
	9/06/86	<5	<5	522	<5	<5
	6/17/86	<5	<5	440	<5	<5
	4/08/86	<5	<5	400	<5	<5

1-9

TABLE 1-2 (Cont'd)

SUMMARY OF SELECTED* PARAMETERS FROM 1985-1986 GROUNDWATER QUALITY DATA

Parameter	Date Sampled	P-1	Monitor Well Number P-2	P-5	P-6	OW-1
Vinyl Chloride	11/12/86	ND	ND	ND	ND	ND
(ug/l)	9/06/86	ND	ND	ND	ND	ND
	6/17/86	ND	ND	ND	ND	ND
	4/08/86	<5	<5	30	<5	<5

-- - Well not yet installed
ND - No data
* - Selected based on noted Ohio EPA concerns.

Analytical data from 1985 and 1986 groundwater samplings are summarized for selected ions in Table 1-2. General increases in chloride, sulfate and magnesium concentrations can be noted in most downgradient wells. Total and hexavalent chromium are non-detectable. Iron concentrations appear representative of natural background conditions. Again, monitor Well P-5 is the only well displaying the presence of volatile organic compounds. The primary VOC's detected were 1,2-Trans-Dichloroethylene, Trichloroethylene, and Vinyl Chloride.

1.2 DEVELOPMENT OF ADDITIONAL BACKGROUND DATA

The following additional background data does not exist at this time and will need to be obtained to fulfill the objectives of the study defined in Section 1.0 of this report:

- o   No volatile organic compound (VOC) data exists for the sludges disposed in the surface impoundments. This information will be necessary to determine if the VOC contamination in well P-5 is related to the surface impoundments.

- o   The existing monitor well network does not effectively monitor the upper portion of the Berea Sandstone in areas where the aquifer thickens (i.e, in the vicinity of P-5).

- o   The existing groundwater elevation data is not sufficient to determine vertical flow gradients within the thicker portion of the Berea Sandstone.

- o   No investigative data exists to evaluate the potential source of the elevated chloride concentrations in upgradient monitor well OW-1.

The proposed investigation is directed towards obtaining the additional data necessary for achieving the previously defined objectives of the study.

SECTION 2

TECHNICAL APPROACH

The Phase 2 Groundwater Quality Assessment Plan for the GMC-Fisher Guide site will include an extensive evaluation of soil and groundwater quality in accordance with Ohio regulations OAC 3745-65-90 through 94 and federal regulations under 40 CFR 265.90 Subpart F. The technical approach proposed for this characterization can be divided into six tasks:

        Task 1 - Definition of study area boundaries
        Task 2 - Geophysical survey
        Task 3 - Waste characterization sampling
        Task 4 - Installation of additional monitor wells
        Task 5 - Sample collection and analysis
        Task 6 - Data interpretation/report of findings

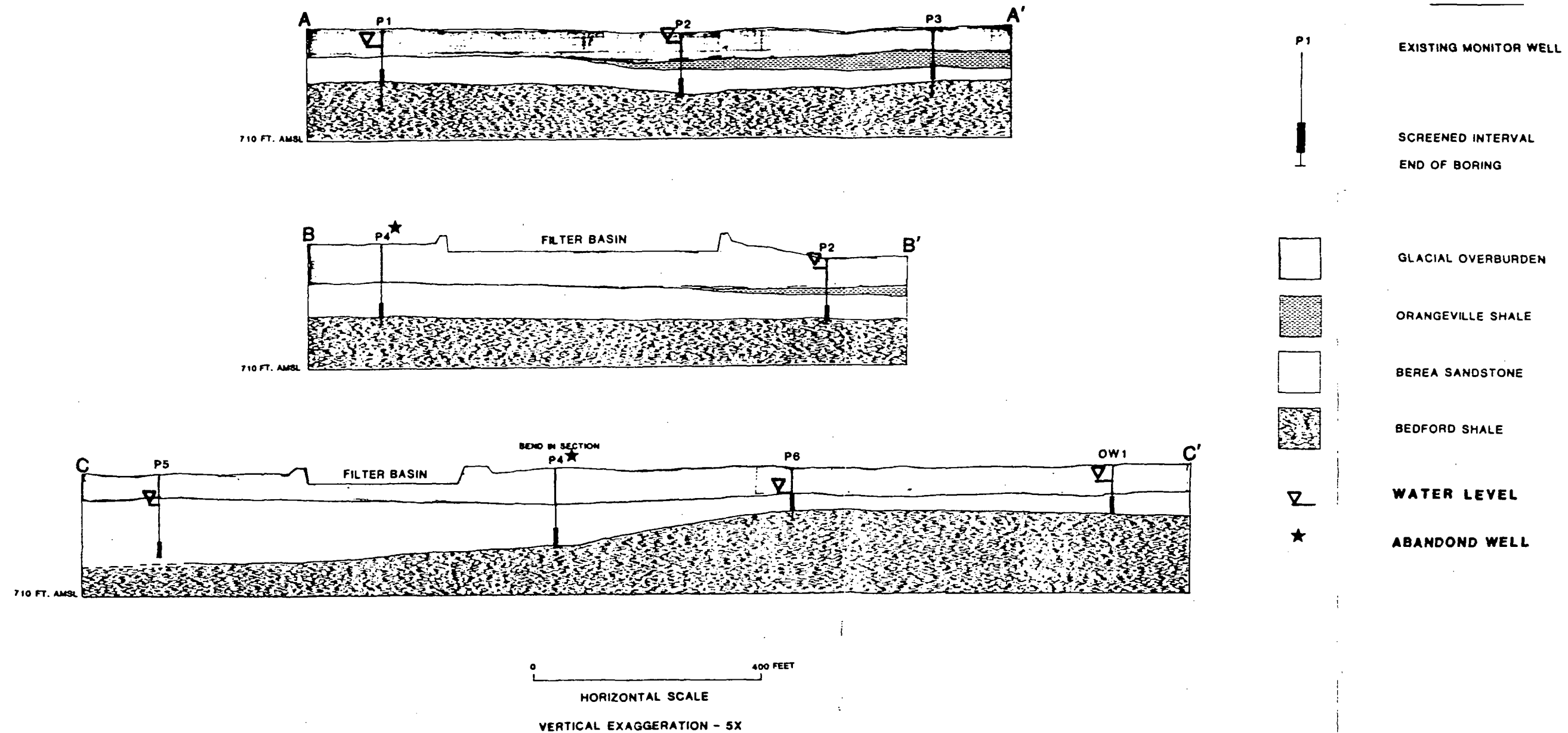Each task will be detailed separately below.

2.1 TASK 1 - DEFINITION OF STUDY AREA

The intent of this groundwater quality assessment plan is to further define and quantify the impact of the surface impoundments on groundwater quality. Surrounding the facility are three past waste disposal areas which are not to be addressed in this plan. The locations of the past disposal areas relative to the surface impoundments are illustrated in Figure 2-1 using the first acetate overlay. The second acetate overlay superimposes a groundwater contour map based on water level elevations obtained in November, 1986. At a certain distance downgradient of the impoundments, it may not be possible to distinguish between effects due to the impoundments and those of the past disposal areas without addressing both issues concurrently.

To obtain data useful to this study without addressing the past disposal areas, a downgradient extent of the study area must be defined within which there is a fair degree of confidence that the water chemistry is impacted primarily by the existing impoundments. The third acetate overlay for Figure 2-1 roughly estimates the downgradient extent of the study area which is primarily influenced by the impoundments. The placement of the boundary at this point is clearly judgmental based on background hydrogeologic interpretations. The geophysical survey defined in Section 2.2 of this report may serve to further refine the placement of the downgradient extent of the study area.

If it is determined that hazardous waste or hazardous waste constituents are present in the groundwater, and it is determined by this study that it is not possible to more accurately define the areal extent of any hazardous waste or hazardous waste constituents emanating from the sludge impoundments, an expanded hydrogeologic study encompassing

2-1

GEOLOGIC CROSS-SECTIONS
GMC-FISHER GUIDE ELYRIA, OHIO

0   400 FEET

HORIZONTAL SCALE

VERTICAL EXAGGERATION - 5X

LEGEND

P1   EXISTING MONITOR WELL

SCREENED INTERVAL
END OF BORING

GLACIAL OVERBURDEN

ORANGEVILLE SHALE

BEREA SANDSTONE

BEDFORD SHALE

▽   **WATER LEVEL**

★   **ABANDOND WELL**

BASED ON BORING LOGS FROM CDM AND EDI ENGINEERING

FIGURE 1-2

WESTON
DESIGNERS · CONSULTANTS
WEST CHESTER   PENNSYLVANIA

DRAWN R. GNAT   DATE 11/29/86

OVERLAY 3 - PROPOSED DOWNGRADIENT BOUNDARY
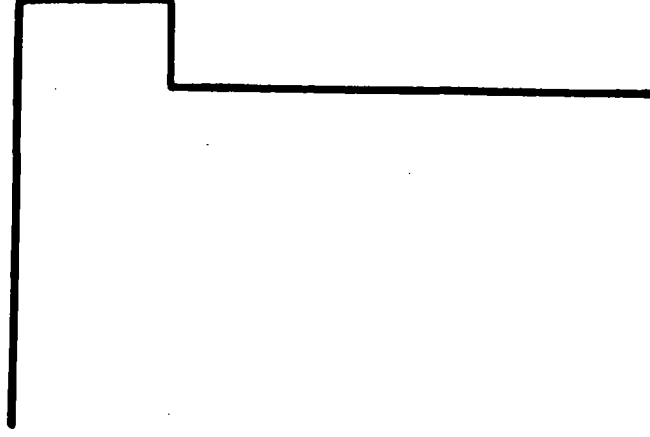
OVERLAY 2 – GROUNDWATER CONTOUR MAP

738.18

744.13

738

740

742

742.40

743

745.53   746

744

746

748

748.54

PAST DISPOSAL AREA
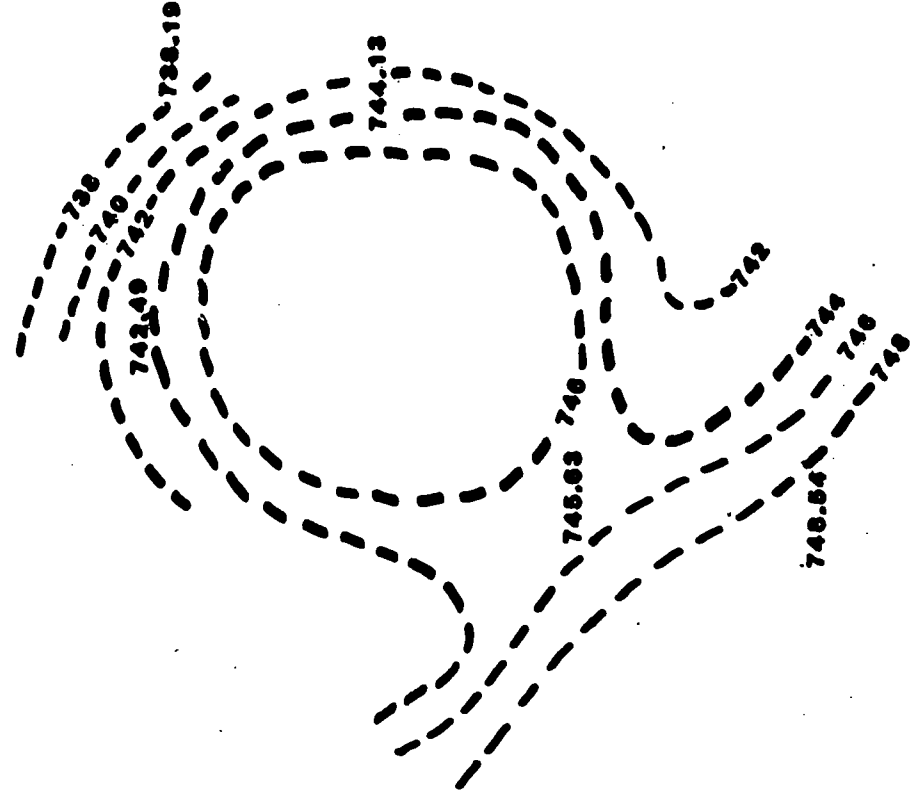
PAST DISPOSAL AREA
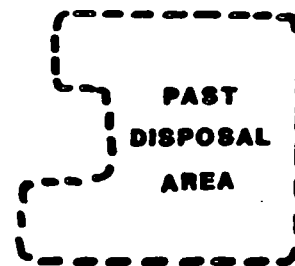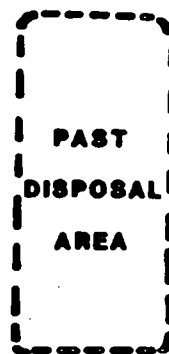
PAST DISPOSAL AREA

FIGURE 2-1 DOWNGRADIENT EXTENT
OF STUDY AREA

the past disposal areas may need to be initiated. It is not possible at this point to specifically outline the structure of the expanded study, however, the study may include a waste characterization of the past disposal areas, additional monitor well points around the periphery of the past disposal areas screened in both the upper and lower portions of the aquifer, and an expanded geophysical survey. If it is determined by the mutual concurrence of the Ohio EPA and GMC that an expanded study is required to further define the extent and magnitude of contamination, the exact approach, options and level of detail will be based on the results of the study proposed herein.

The study boundary must also be defined vertically to develop an appropriate groundwater quality assessment plan. Using the RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (OSWER-9950.1) for reference, the program must address the uppermost aquifer of which the lower extent is marked by the first confining layer. A review of previous well logs from on-site borings suggests the Berea Sandstone to be the uppermost aquifer and the Bedford Shale, which underlies the Berea Sandstone, to be the first confining layer. Locally, in areas where the Berea Sandstone is absent, small quantities of water are withdrawn from the fractured upper portion of the Bedford Shale as no other shallow aquifer is available. In areas where the Berea Sandstone is present (i.e. in the vicinity of Elyria, Ohio), the sandstone is the primary shallow aquifer with generally no water being drawn from the Bedford Shale. Within these areas, due to the contrasting permeabilities between the sandstone and the underlying shale, the Bedford Shale can be considered a confining layer. Discussions with the Ohio Geologic Survey and Ohio Department of Natural Resources personnel s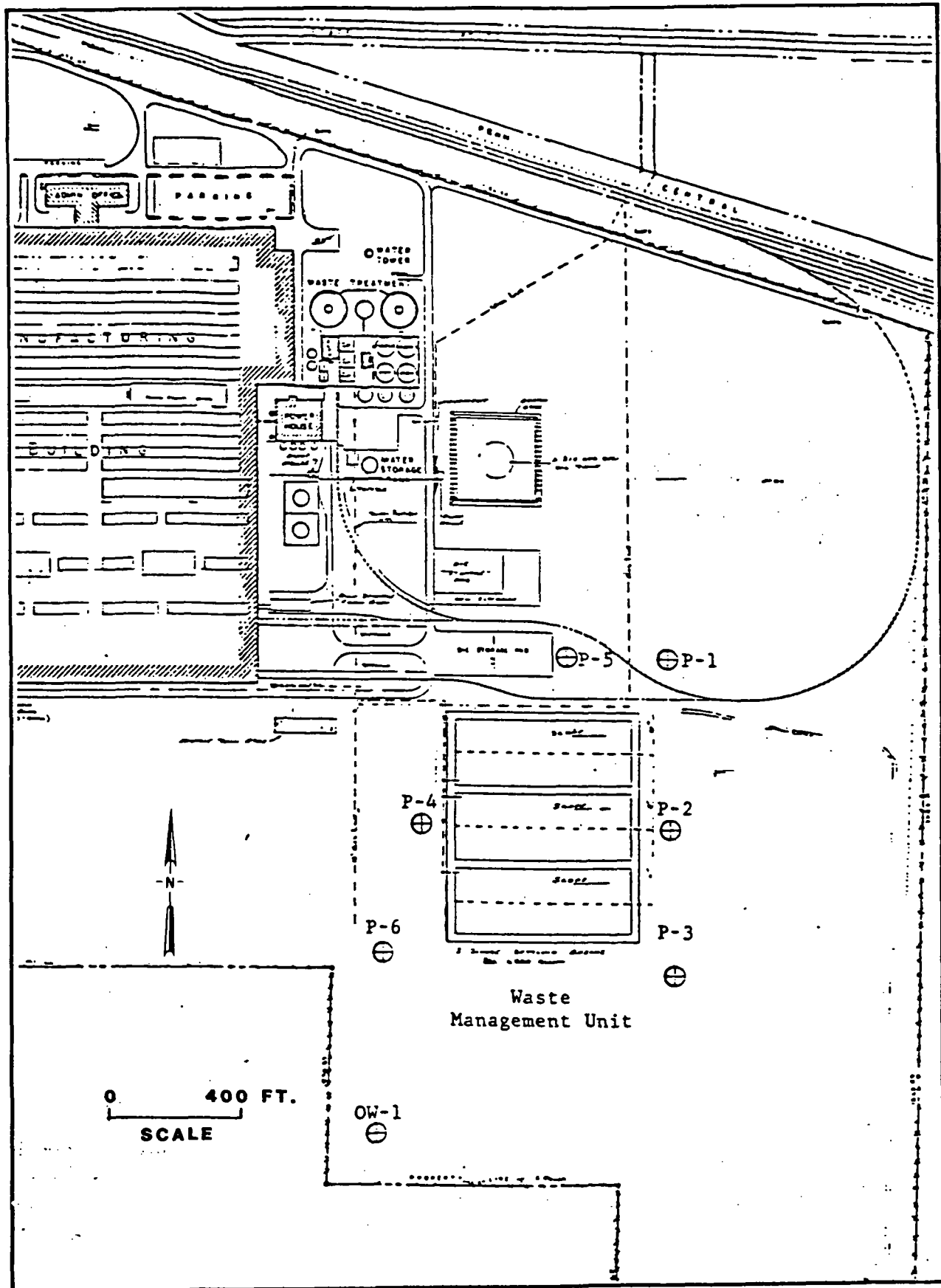upport these interpretations and therefore, for the purposes of this GWQAP, the lower extent of the study area will coincide the top of the Bedford Shale or the base of the Berea Sandstone. If it is determined in this study that hazardous waste or hazardous waste constituents have been released to groundwater as a result of leakage from the surface impoundments, additional monitoring wells may need to be installed into the Bedford Shale unit.

2.2   TASK 2 - GEOPHYSICAL SURVEY

An EM-34 terrain conductivity survey is proposed to be performed at the GMC-Fisher Guide site. The purpose of the terrain conductivity survey is to determine the boundaries of a suspected ionic plume, located southeast of the plant. More specifically, the ionic plume is suspected to exist in the vicinity of, and originate from, the three surface impoundents. The primary constituents of the ionic plume are believed to be chloride and sulfate.

Slightly elevated chloride levels have also been detected in OW-1 which is hydraulically upgradient of the three impoundments. This suggests that there may be an

2-3

unidentified source of chloride contamination that exists upgradient of the impoundments. The EM-34 survey will be used to determine if there is any unidentified upgradient source.

In addition to defining the extent of the ionic plume, the results of the survey will be used to evaluate and refine, as necessary, the downgradient boundary of the study area and to determine the most strategic monitoring well locations.

An electromagnetic survey is an appropriate technique to determine the extent of the plume. Electromagnetic techniques of measuring terrain conductivity operate by imparting an alternating current to a transmitter coil placed on the earth's surface. The current passing through the transmitter coil produces a magnetic field which, in turn, induces small currents in the underlying strata. Currents within the geologic materials produce a secondary magnetic field which is sensed by the receiver coil. It has been shown that the ratio of the magnetic field detected by the receiver coil to the magnetic field produced by the transmitter coil is directly proportional to terrain conductivity (Geonics, 1980). This allows terrain conductivity to be read directly from the instrument in millimhos per meter (mmhos/m).

For the EM-34 survey at the GM site, measurements will be taken in the vertical dipole orientation with a coil separation of 10 meters (32.8 feet) using a Geonics Model EM-34 terrain conductivity meter. Vertical dipole measurements with a 10 meter coil separation yield an effective depth of exploration of 15 meters (49.2 feet) with minimal contribution from surficial materials. The maximum contribution to each reading taken in the vertical dipole mode is from a depth of approximately 4 meters (13.1 feet).

The EM survey readings will be taken at 100-foot intervals via a pre-established grid system. The proposed grid area is shown in Figure 2-2. More closely spaced readings will be taken at locations where it is deemed necessary to collect additional information. Conversely, if readings over a large area appear to be within background, the station spacing may be increased until elevated readings are encountered. The wooded area south of the impoundments may inhibit access to some grid points, however, this is not felt to be a crucial issue. The geophysical survey will extend over and beyond the past disposal area east of the impoundments to obtain additional downgradient information. The northern boundary will coincide with the two past disposal areas north of the impoundments.

Upon completion of the EM survey, the data will be computer contoured using the CPS-1 contouring package. Results of the geophysical survey and recommendations for exact siting of monitor wells and, if necessary, locations of borings to
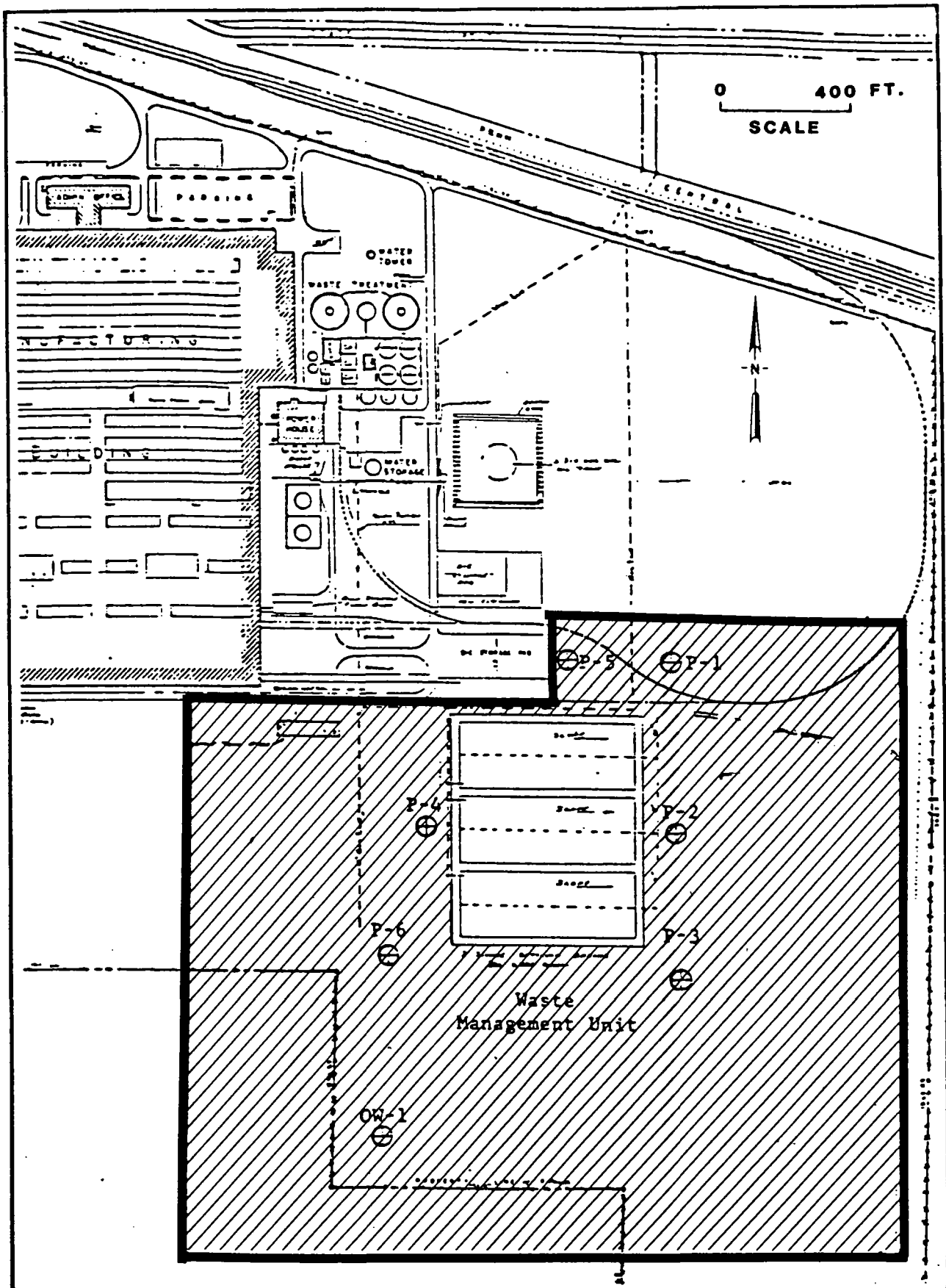
FIGURE 2-2 GRID AREA FOR GEOPHYSICAL SURVEY

"true" the geophysical data will be presented to the Ohio EPA for review.

2.3 TASK 3 - WASTE CHARACTERIZATION SAMPLING

A review of existing analytical data for the surface impoundment sludges indicates that no volatile organic analyses were performed on the sludges. As one step in determining if the VOCs in monitor well P-5 are originating from the impoundments, the sludges within the surface impoundments will be sampled and tested for Hazardous Substance List volatile organic compounds. (A specific list of compounds is given in Attachment 3.)

A total of six grab samples will be collected, two from each impoundment. Each impoundment will be divided in half. One grab sample will be collected from each impoundment half. Where possible, the sample will be collected using a stainless steel hand auger to a depth of approximately four feet. In the portions of the impoundments where the sludge is not solid, a stainless steel bucket will be used to collect a representative liquid sample. Upon sample collection, appropriate sample aliquots will be placed into laboratory prepared containers and immediately shipped on ice to the contracted laboratory for analysis.

Decontamination of all sampling equipment will consist of a pesticide grade hexane wash, a methanol rinse, and a final deionized water rinse.

2.4 TASK 4 - SUPPLEMENTAL MONITOR WELL INSTALLATION

Groundwater flow patterns developed from the existing monitoring wells at the GMC-Fisher Guide facility indicate an asymetrical, groundwater mound centered around the impoundments (Figure 1-3) . This mounded pattern is common where significant head differentials are observed. Based upon existing water level measurements, the apparent regional flow in the Berea Sandstone is to the northeast. The Berea Sandstone is the primary hydrostratigraphic unit beneath the facility.

Presently seven monitoring wells have been installed near the impoundments. One of these wells (P-4) was damaged and has been properly closed. The existing strategy is oriented towards monitoring the base of the Berea Sandstone. Although this strategy is sufficient for most of the site where the thickness of the Berea Sandstone is not much greater than the influence zone of the wells, it is insufficient where the sandstone unit thickens, particularly in the vicinity of existing monitor well P-5.

The revised monitoring well strategy proposes to replace Well P-4 and install four additional monitor wells (monitor wells 5S, 7, 8, and 9). The proposed locations for these wells are illustrated in Figure 2-3. Cross-sections relating the

FIGURE 2-3   PROPOSED MONITOR WELL LOCATIONS
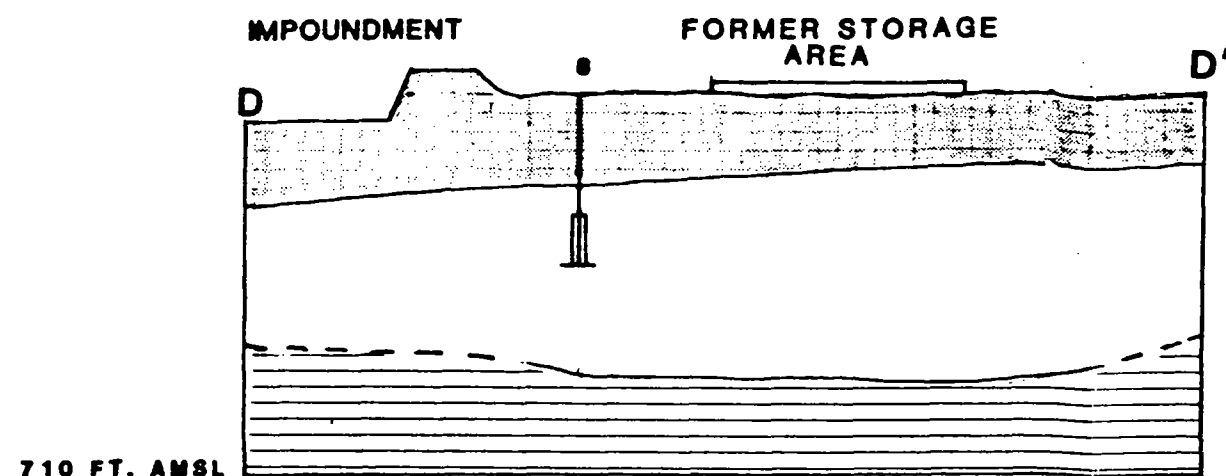
Legend:
- ● PROPOSED WELL
- ⊕ EXISTING WELL
- ▲ REPLACEMENT WELL
- E——E' CROSS-SECTION LINE

SCALE

0   400 FEET

Waste Management Unit

2-7
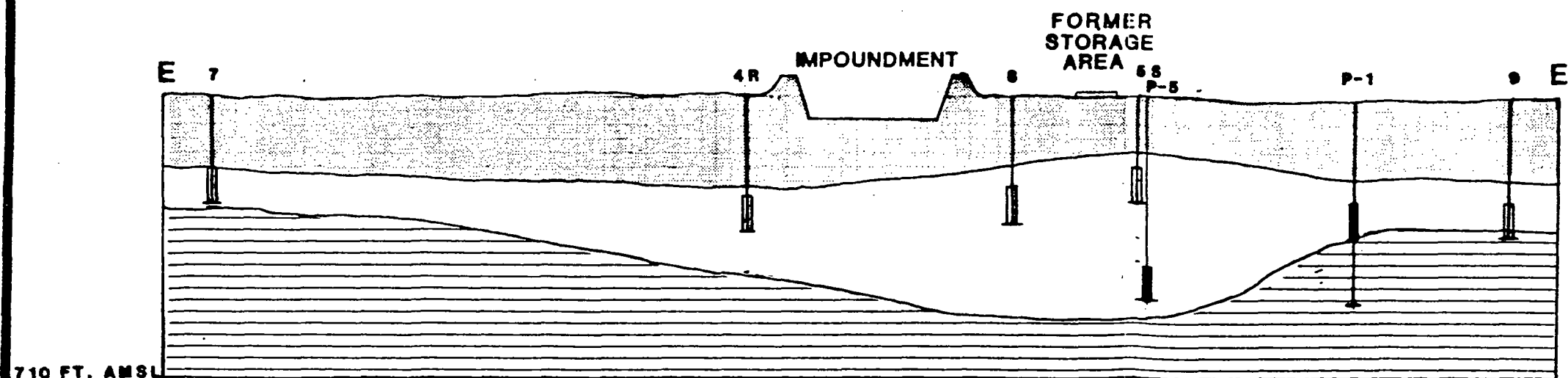
FIGURE 2-4 CROSS-SECTIONS SHOWING PROPOSED WELL NETWORK

TABLE 2-1
PROPOSED EXPANDED MONITOR WELL NETWORK
FOR WELL LOCATIONS REFER TO FIGURE 2-3

Monitor Well No.	Approx. Total Depth (ft.)	Approx. Screened Interval (ft. below surface)	Rationale
4R	19	14-19	Replace non-servicable well P-4. Will be located slightly north of original location for better hydrologic control for defining groundwater mound and for quantifying the presence of hazardous or non-hazardous constituents within the Berea Sandstone. No well cluster is proposed due to the expected thickness of sandstone in the area.
7	15	10-15	Additional background well. Will enhance upgradient control for water quality, extent of groundwater mound, and stratigraphy. No well cluster is proposed due to the expected thickness of sandstone.
8	18	13-18	Downgradient of impoundments but uogradient of old storage pad. Will yield information necessary to investigate origin and extent of VOC contamination in the area. No well cluster is proposed due to proximity of potential sources.
5S	15	10-15	Shallow well clustered next to existing deeper well P-5. Will allow monitoring for potential downgradient migration of lighter constituents in the upper portion of the Berea Sandstone. Water levels from this well cluster will yield information on vertical gradients within this portion of the aquifer.
9	20	15-20	Will monitor furthest possible downgradient location without potential interference from past disposal units. Will yield information regarding the downgradient extent of hazardous or non-hazardous constituents emanating from the impoundments. No well cluster is proposed due to the expected thickness of sandstone in this area.

proposed wells to site stratigraphy are given in Figure 2-4. Approximate well depths, screening intervals, and placement rationale are summarized in Table 2-1.

Monitoring well 4R will replace its closed, non-functioning counterpart. The location of well 4R will be slightly north of its original location to give better hydrologic control for defining the groundwater mound. Monitor well 7 will be located approximately 400 feet west of the southwestern corner of the southern most impoundment. Based on present hydrogeologic interpretations of the groundwater mound size and geometry, the location of this well will enhance upgradient control for both water quality and potentiometric surface elevation. It will supply additional stratigraphic control for the Berea Sandstone and provide better definition of the upgradient extent of the groundwater mound. If it is determined after installation that well 7 may still be impacted by the groundwater mound, an additional groundwater monitoring point may need to be installed further upgradient of the proposed location.

Monitor wells 8 and 5S will be used in conjunction with existing well P-5 to determine if the VOC contamination in this area is related to the surface impoundments. Monitor well 8 will be located north (downgradient) of the impoundments but south (upgradient) of the former dye storage pad to isolate potential volatile constituents emanating from the impoundments. This well will be screened in the upper part of the Berea Sandstone due to its proximity to the potential source, thus enabling it to monitor for both light and heavy constituents. Monitor well 5S will be clustered next to the existing deeper well P-5. The new well will be screened in the upper portion of the Berea Sandstone. In addition to providing an effective monitoring point for downgradient migration of both light and heavy constituents, the water levels obtained from this well cluster will be used to determine vertical gradients within this portion of the aquifer.

Monitor well 9 will be located at the furthest downgradient point possible without being potentially impacted by the past disposal areas. The exact placement of this well will be refined according to the results of the geophysical survey described in Section 2.2 of this plan. The well will be screened at the base of the Berea Sandstone which at this point is anticipated to be approximately only 9 feet thick, based on the well log from existing well P-1.

Two shallow soil borings will be performed adjacent to existing monitor wells P-2 and P-3. The primary purpose of these borings will be to determine the nature of the overlying glacial till materials in these areas. Particular attention will be given to defining whether water table conditions exist within the glacial till. The borings will extend only into the top of the underlying Orangeville Shale. If it is determined that water table conditions exist within

the glacial overburden, and if hazardous waste or hazardous waste constituents have been released to groundwater as determined by the proposed study, then additional groundwater monitoring points may need to be installed at these points and screened in the glacial overburden.

The expanded monitoring well network will provide better hydrogeologic definition of the groundwater mound, additional points for quantifying and assessing the extent of any contaminant plume emanating from the surface impoundments, sufficient data to determine whether the VOC contamination in monitor well P-5 can be attributed to the impoundments and information to help determine the rate of vertical migration of constituents within the Berea Sandstone. Only one well cluster in the vicinity of existing well P-5 is proposed because stratigraphically, this is the only portion of the site known at this time, under which the aquifer thickens to the point that a well cluster is necessary to effectively monitor groundwater quality. If it is determined on the basis of this study that hazardous waste or hazardous waste constituents have entered groundwater as a result of leakage from the surface impoundments, additional monitoring points may need to be installed into the Bedford Shale.

As previously discussed, if the impact of the adjacent past disposal facilities is such that it precludes the ability to define the extent of any hazardous waste or hazardous waste constituents emanating from the sludge impoundments, additional groundwater monitoring points may need to be installed. At this point, it is not possible to provide the exact number or location of additional wells, however, the wells will be placed in locations allowing for the discrimination between constituents associated with the impoundments and those associated with the past disposal areas. The siting and construction of these wells will be performed with accepted hydrogeologic practices and in conformance with the RCRA Groundwater Monitoring Technical Enforcement Guidance Document (OSWER-9950.1).

2.4.1 Monitoring Well Construction

Prior to drilling each well, the drill rig, all drillers tools, and all well construction materials will be thoroughly decontaminated using a portable steam cleaner. Drilling and sampling will be completed utilizing a water washed, rotary tricone drilling configuration. Drilling water will be obtained from the GMC-Fisher Guide plant which obtains its water from the City of Elyria municipal water supply. A sample of the water will be collected and analyzed prior to drilling activities to document the water quality. A split-spoon sampler will be used to obtain subsurface soil samples through the unconsolidated glacial overburden. The split spoon samples will be collected continuously for purposes of defining subsurface stratigraphy. Particular attention will be given to defining the water table, permeable zones, soil moisture conditions and mottling within

the glacial overburden. Upon reaching the Berea Sandstone, the remainder of the hole will be logged from cuttings being washed to the surface. All drill cuttings will be disposed of within the surface impoundment boundaries.

Monitor wells 7, 9 and 4R will be constructed using 2-inch diameter, flush-threaded PVC casing (Figure 2-5). The screen length shall be 5 feet with continuous slot openings of 0.010 inches and tipped with a PVC plug on the bottom of the screen. The annular space around the screen will be back-filled with silt free flint sand (WB 40 grade) to a height no more than two feet above the top of the screen. A two-foot thick seal of compressed sodium bentonite pellets will be placed above the sand pack. The pellets will then be soaked with distilled water and allowed to expand approximately 15 to 20 minutes. The remaining annular space will be filled with a cement-sodium bentonite grout placed with a tremie pipe. The PVC riser will be covered with a loosely fitting, vented PVC cap. A four-inch diameter galvanized steel, locking protective casing will be installed at the surface with a concrete anchor and runoff diversion apron. In heavy traffic areas three, eight-foot guard posts may be installed around the well head to prevent vehicular damage to the well. The protector casing will include a drain hole to prevent water from standing and freezing between the two casings.

Monitor Wells 8 and 5S will be installed in the vicinity of documented VOC contamination and will therefore be constructed of stainless steel screen and riser. All other construction details will be similar to those presented above.

Following the installation of well construction materials, the well shall set for a period no less than one week prior to any development procedures to allow the grout to properly cure. The well will be developed by surging and pumping until five well volumes have been removed and clear water is obtained during pumping. The pH of the water will be monitored and development will continue until stable conditions have been documented. Following development, a slug test, as described in Section 2.4.2 will be performed on each new well to document the sensitivity of the well and provide data for calculating the hydraulic conductivity of the screened interval.

2.4.2 Hydraulic Conductivity Testing of Wells

Field test methods are generally more representative and reliable than laboratory methods for estimating aquifer characteristics. As recommended in the U.S. EPA groundwater monitoring guidance document (OSWER-9950.1), hydraulic conductivity can be estimated in the field using either single well tests (slug tests) or multiple well tests (pump tests).

WESTON

Overburden

Locking 4 Inch
Protective Casing

Concrete Anchor and
Runoff Diversion Apron

2 Inch
Diameter Pipe

Cement Bentonite
Grout

2 Ft.

1 Ft.

Bentonite Pellets

**Berea
Sandstone**

5 Ft.

2 Inch Diameter
Well Screen, .010 Slot

Flint Sand Filter

8 Inch
Diameter Borehole
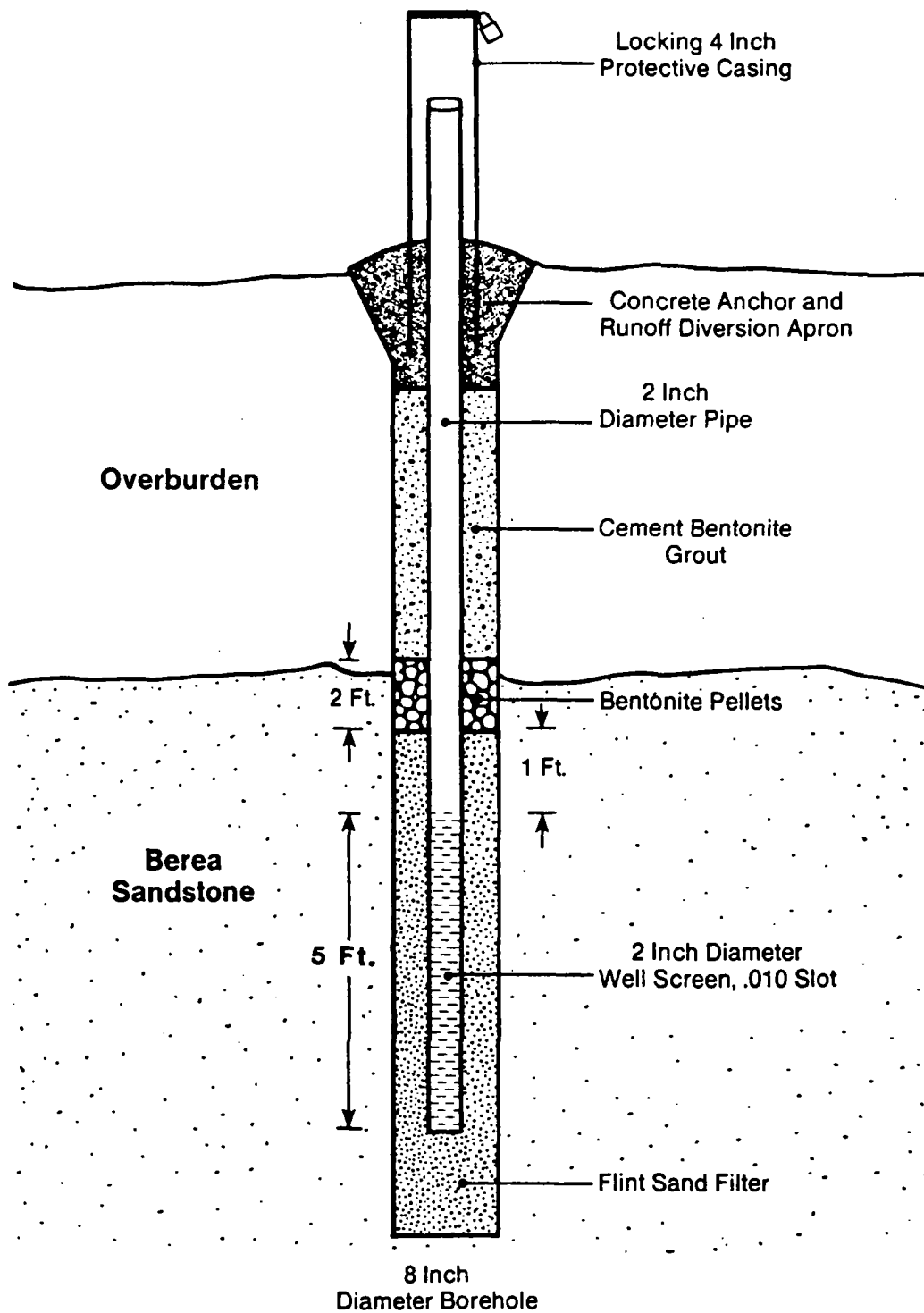
Not to Scale

FIGURE 2-5 SINGLE WELL INSTALLATION DETAILS

To better characterize and estimate the hydrogeologic character of the Berea Sandstone in the vicinity of the surface impoundments, slug tests will be performed at each new monitoring well location (including existing monitor well P-5). The slug test procedure will be:

o   Determine the static water level

o   Introduce a cylinder of known volume into the well to displace an equivalent volume of water.

o   Perform depth to water measurements at preset time intervals until water level returns to static conditions.

o   Remove cylinder from the well again displacing the water level in the well.   .

o   Perform depth to water measurements at preset time intervals until water level returns to static conditions.

Water level measurements during the recovery period will be obtained using an SE1000 series electric transducer system developed by In-Situ Incorporated. All measuring instruments will be carefully decontaminated using an Alconox solution wash and a deionized water rinse rather than the hexane decontamination sequence as hexane and methanol may attack delicate components of the pressure transducer of the SE1000.

The mathematical computation of test data will be done according to procedural analysis presented by Bouwer and Rice, 1977 (refer to Attachment 2). All raw data and calculations will be kept on file for documentation purposes.

For wells noted to be screening the top of the water table, bail down-recovery tests will be performed as the above method is not applicable in situations where the sand pack is not fully saturated.

2.5   TASK 5 - ENVIRONMENTAL SAMPLING PROGRAM

The proposed sampling program encompasses both groundwater sampling to define the impact of the surface impoundments on existing groundwater quality and soil sampling to help determine if the impoundments are the source of VOC contamination in existing monitor well P-5.

2.5.1   Groundwater Sampling and Analysis

Groundwater samples will be collected from all new and existing monitor wells to quantify the impact of the impoundments on local groundwater quality. The proposed analytical program is summarized in Table 2-2 with appropriate analytical protocols cited in Table 2-3. The following procedures will be used to collect the samples:

TABLE 2-2

SUMMARY OF PROPOSED ANALYSES FOR GROUNDWATER AND
SOIL SAMPLES TO BE COLLECTED AT THE GMC-FISHER GUIDE FACILITY
IN ELYRIA, OHIO

	Groundwater	Soil
HSL Volatile Organic Compounds*	X	X
HSL Inorganics (filtered)*	X	
HSL Inorganics (non-filtered)*	X	
Hexavalent Chromium	X	
Chloride	X	
Phenols	X	
Sulfate	X	
TOC	X	
TOX	X	X
Spec. Conductivity	X	
pH	X	
Temperature	X	

* For a list of compounds refer to Attachment 3.
  HSL inorganics include iron, manganese, sodium, copper,
  nickel and zinc.

Note: Groundwater samples for dissolved inorganics will be
field filtered using a .45 micron filter.

TABLE 2-3

ANALYTICAL PROTOCOLS TO BE USED FOR
CHEMICAL ANALYSIS OF SAMPLES FROM
THE GMC-FISHER GUIDE SITE INVESTIGATION

Analysis	Protocol
HSL Volatile Organic Compounds - Water	Method 624
HSL Volatile Organic Compounds - Solid	Method 8240
HSL Inorganics - Water	*
Hexavalent Chromium	Method 218.4
Phenols	Method 4020.2
Total Organic Carbon	Method 415.1
Total Organic Halogen - Water	Method 9020
Total Organic Halogen - Soil	Modified RCRA Method 9020
Chloride and Sulfate	U.S. EPA 600 - Methods of Chemical Analysis of Water and Waste

* Analytical methods as specified in the U.S. EPA Contract Laboratory Program July 1985 Inorganics Statement of Work.

o   Depth to water in the well will be measured with an electric sounder or a weighted fiberglass tape. The weight will be designed to create a popping sound on contact with the water.

o   Based on the water level measurement and the depth of the well, the volume of standing water in the well will be calculated.

o   The well will be purged using a teflon bailer until three casing volumes of water have been removed.

o   If the well is purged dry before three casing volumes of water have been removed, the well will be allowed to recharge for 15 minutes and then bailed dry again.

o   The water sample will be obtained using a teflon bailer. The water will be carefully poured from the bottom of the bailer directly into sample containers. Extreme care will be taken to minimize agitation during transfer of the sample. All volatile organic sample containers will be filled completely, sealed and closely inspected to ensure no trapped air space within the vial which may effect subsequent analysis.

o   All sampling and purging equipment will be carefully decontaminated using a hexane wash, a methanol rinse and a final deionized water rinse.

One duplicate and one blank will be collected and analyzed for quality assurance/quality control purposes. Specific conductivity, pH and temperature measurements will be taken in the field by the sampling team. As per the RCRA Groundwater Monitoring Technical Enforcement Guidance Document (OSWER-9950.1), samples will be collected in the following order: volatile organics, TOX, TOC, total metals, dissolved metals, phenols, sulfate and chloride.

For all new monitor wells initial background concentrations will also be established for future long term use as defined by 40CFR 265.92. On a quarterly basis for one year, all new wells will be sampled and analyzed for chloride, iron, manganese, phenols, sodium, sulfate, pH, specific conductance, TOC and TOX. The last four parameters noted are indicator parameters. For each of these at least four replicate measurements will be obtained for each sample and the initial background arithmetic mean and variance will be determined by pooling the replicate measurements for the respective parameter concentrations.

2.5.2   Subsurface Soil Sampling and Analysis

During the drilling of borings for monitor wells 8 and 5S, soil samples will be collected from split-spoon samples of

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the unconsolidated glacial overburden. One sample will be analyzed from each location for a total of two samples. The results will be used to help determine if VOC's documented in existing monitor well P-5 are potentially originating from the surface impoundments.

Split spoon samples will be collected continuously through the glacial overburden. Upon retrieval, each spoon will be opened and screened in the field for volatile organic compounds using a photoionization detector or an organic vapor analyzer. Upon screening, the sample will be immediately placed into a laboratory prepared container and sealed. Upon completion of the boring, the sample showing the highest meter deflection will be the sample sent for chemical analysis. If no meter deflection is recorded for any of the samples for a particular boring then the last sample collected will be sent for chemical analysis. As before, decontamination will consist of a pesticide grade hexane wash, a methanol rinse and a final deionized water rinse. All soil samples will be analyzed for Hazardous Substance List volatile organics compounds and total halogenated organics as noted on Table 2-2 with analytical protocols as specified on Table 2-3.

2.5.3 Sample Shipment

Shipment of groundwater and soil samples will be accomplished in containers and packaging materials designed to prevent tampering, breakage, spills and contamination of samples. Where appropriate, samples requiring refrigeration will be placed in waterproof containers packed with freezer packs or ice. A chain-of-custody record will accompany the samples in the container during shipment. The shipment of samples in sample bottles will comply with applicable DOT regulations.

2.5.4 Chain-Of-Custody Documentation

The groundwater and soil sampling program will include chain-of-custody control of sample integrity to ensure against manipulation and/or unknowing contamination of samples. Chain-of-custody procedures document the custody of the sample and provide a written tracking mechanism that lists the person responsible for the sample before its final destination at the laboratory for analysis.

GMC-Fisher Guide will use the existing chain-of- custody record supplied by the U.S. Environmental Protection Agency, Office of Enforcement (Figure 2-6) or equivalent. The following information will be entered:

1.   The billing code or other identifying project number.

2.   The identifying facility and project name.

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ENVIRONMENTAL PROTECTION AGENCY
Office of Enforcement

CHAIN OF CUSTODY RECORD

REGION 5
230 South Dearborn Street
Chicago, Illinois 60604

PROJ. NO.	PROJECT NAME					NO. OF CON- TAINERS							REMARKS
SAMPLERS: *(Signature)*												
STA. NO.	DATE	TIME	COMP	GRAB	STATION LOCATION							

Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*
Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date / Time	Received by: *(Signature)*
Relinquished by: *(Signature)*	Date / Time	Received for Laboratory by: *(Signature)*	Date / Time	Remarks	

Distribution: White — Accompanies Shipment. Pink — Coordinator Field Files. Yellow — Laboratory File

5- 111694

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CONSULTANTS

FIGURE 2-6 SAMPLE CHAIN OF CUSTODY

3. The person or persons collecting the sample sign the document.

4. The number of the sampling points, if available (i.e., well number, etc.).

5. The date of the sample.

6. The time of the sample.

7. Any comment that will facilitate sample preparation and analysis, or any mitigating circumstances that may affect sample analytical results.

8. The signature of the person who relinquishes the sample.

2.5.5 Quality Control

Quality control procedures will be implemented to assure the validity of sampling results. Specific quality control procedures will include the analysis of the following:

1. One groundwater field blank
2. One groundwater and one soil duplicate.

Trip blanks will be included with each cooler shipment; however, these will not be analyzed unless contamination during shipment is suspected.

The contracted laboratory will be required to outline all internal quality assurance/quality control measures. Full documentation packages will be required as part of the laboratory analytical report. All such documentation will be kept on file by WESTON through the end of the project. The documentation will then be signed over to GMC-Fisher Guide for storage.

2.6 TASK 6 - DATA INTERPRETATION/REPORT OF FINDINGS

Monthly progress reports shall be prepared throughout the duration of the site investigation and submitted to GMC-Fisher Guide. The monthly reports will include progress made, problems encountered, problems resolved, planned activities and budget status.

Upon completion of the site investigation and receipt of all analytical testing results, a detailed hydrogeologic assessment of the site will be made. All findings will be summarized in a final site investigation report. The report will include the following:

o Concise summaries of all on-site activities.

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o   A detailed discussion of regional and site specific
        hydrology.

o   A detailed assessment of the impact of the sludge
        impoundments on local groundwater quality with
        respect to federal and state regulations.

SECTION 3

SCHEDULE

It is estimated that it will take approximately 20 weeks from the start of field work to obtain all necessary data and produce a final report of findings. A breakdown of specific task schedules is given in Figure 3-1. Unforeseen field problems, laboratory delays or delays due to regulatory agency reviews may increase execution times for the various tasks.

The definition of the study area (Task 1) was performed as part of this plan and therefore does not show a project time line. The actual study area may be refined based on results of the geophysical survey. The geophysical survey is estimated to require three weeks to obtain all readings and produce a conductivity contour map of the area. Collection of waste characterization samples may be performed concurrently with the geophysical survey. Four weeks are allowed for laboratory analysis.

Well installation will begin upon receipt of geophysical interpretations which will be used to finalize proposed well locations. Drilling and well construction is estimated to take up to two weeks. The grout will be allowed at least one week to properly cure prior to well development. Slug testing of the wells will take up to one week. Groundwater sampling will be performed prior to the slug testing. Soil sampling will be performed during drilling activities. Four weeks are allowed for laboratory analysis.

A final report of findings will be issued six weeks after receipt of all analytical data.
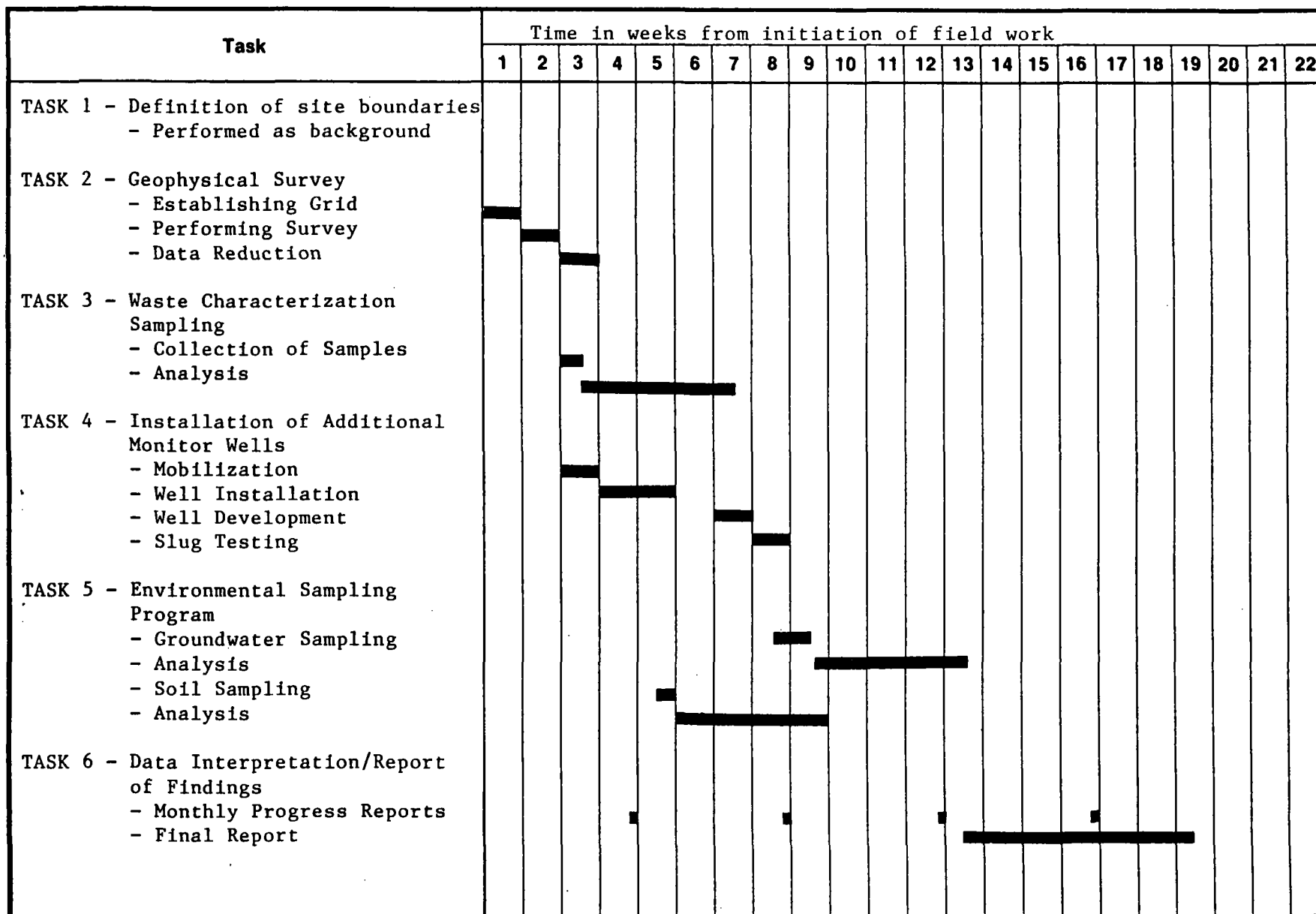
FIGURE 3-1 PROPOSED SCHEDULE OF ACTIVITIES

Task	Time in weeks from initiation of field work
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

TASK 1 – Definition of site boundaries
    – Performed as background

TASK 2 – Geophysical Survey
    – Establishing Grid
    – Performing Survey
    – Data Reduction

TASK 3 – Waste Characterization Sampling
    – Collection of Samples
    – Analysis

TASK 4 – Installation of Additional Monitor Wells
    – Mobilization
    – Well Installation
    – Well Development
    – Slug Testing

TASK 5 – Environmental Sampling Program
    – Groundwater Sampling
    – Analysis
    – Soil Sampling
    – Analysis

TASK 6 – Data Interpretation/Report of Findings
    – Monthly Progress Reports
    – Final Report

WESTON

REFERENCES

EDI Engineering and Science, July 1985. Soil Borings and Geotechnical Data.

Groundwater Technologies, Inc. February, 1985. Groundwater Quality Assessment.

Camp, Dresser and McKee, May 1981. Soil Boring and Well Construction Details.

U.S. EPA, September 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document OSWER-9950.1

Hartzell, Glenn W., 1980. Groundwater Resources of Lorain County. Ohio Department of Natural Resources, Div. of Water.

Ohio Environmental Protection Agency, November 1986. Letter Summarizing Ohio EPA Comments on Original Groundwater Quality Assessment Plan - Phase 2.

Bouwer, H. and Rice, R.C., June 1986. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research Vol. 12, No. 3.

Geonics Limited, 1980. Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers. Technical Note TN-6.

ATTACHMENT 1

BACKGROUND DATA FOR INDICATOR PARAMETERS

SECTION I REPORT VALUES OF INDICATOR PARAMETERS FROM SAMPLES COLLECTED DURING
BASELINE YEAR. OAC 3745-65-94(A)(2)(b)

Well ID	Date Sampled	TOH (mg/L)	TOC (mg/L)	pH S.U.	Specific Conductance uMHOS
P1, IN	01-26-82	< .1	< 1	7.05	1600
		< .1	< 1	7.05	1550
		< .1	< 1	7.05	1600
		< .1	< 1	7.10	1625
	05-05-82	< .1	< 1	6.71	1450
		< .1	< 1	6.70	1450
		< .1	< 1	6.75	1400
		< .1	< 1	6.71	1400
	08-24-82	< .1	< 1	6.85	1600
		< .1	< 1	6.88	1625
		< .1	< 1	6.84	1625
		< .1	< 1	6.92	1600
	11-16-82	< .1	< 1	7.21	1650
		< .1	< 1	7.24	1575
		< .1	< 1	7.22	1575
		< .1	< 1	7.20	1625
	Mean	<.1	<1	6.97	1559
	Variance	0	0	0.039	7156

SECTION 1   REPORT VALUES OF INDICATOR PARAMETERS FROM SAMPLES COLLECTED DURING
BASELINE YEAR.   OAC 3745-65-94(A)(2)(b)

Well ID	Date Sampled	TOH (mg/L)	TOC (mg/L)	pH S.U.	Specific Conductance uMHOS
2, IN	01-25-82	<.1	< 1	7.30	1150
		<.1	< 1	7.30	1175
		<.1	< 1	7.25	1150
		<.1	< 1	7.30	1175
	05-05-82	<.1	< 1	6.75	1200
		<.1	< 1	6.75	1150
		<.1	< 1	6.77	1150
		<.1	< 1	6.75	1150
	08-24-82	<.1	< 1	6.92	1425
		<.1	< 1	6.95	1400
		<.1	< 1	7.01	1375
		<.1	< 1	6.94	1400
	11-16-82	<.1	< 1	7.21	1100
		<.1	< 1	7.21	1150
		<.1	< 1	7.20	1150
		<.1	< 1	7.15	1150
	Mean	<.1	< 1	7.05	1216
	Variance	0	0	0.047	12573

SECTION 1   REPORT VALUES OF INDICATOR PARAMETERS FROM SAMPLES COLLECTED DURING
BASELINE YEAR.   OAC 3745-65-94(A)(2)(b)

Well ID	Date Sampled	TOH (mg/L)	TOC (mg/L)	pH S.U.	Specific Conductance uMHOS
P5, IN	01-25-82	< .1	< 1	7.25	1350
		< .1	< 1	7.35	1300
		< .1	< 1	7.40	1375
		< .1	< 1	7.35	1300
	05-05-82	<.1	< 1	7.10	1375
		<.1	< 1	7.14	1375
		<.1	< 1	7.10	1400
		<.1	< 1	7.10	1350
	08-24-82	<.1	< 1	6.96	1525
		<.1	< 1	7.02	1500
		<.1	< 1	7.01	1525
		<.1	< 1	6.98	1500
	11-16-82	<.1	< 1	7.01	1325
		<.1	< 1	7.01	1300
		<.1	< 1	7.04	1350
		<.1	< 1	7.01	1325
	Mean	<.1	< 1	7.11	1386
	Variance	0	0	0.021	6581

ECTION 1   REPORT VALUES OF INDICATOR PARAMETERS FROM SAMPLES COLLECTED DURING
BASELINE YEAR. OAC 3745-65-94(A)(2)(b)

ell ID	Date Sampled	TOH (mg/L)	TOC (mg/L)	pH S.U.	Specific Conductance uMHOS
P6, UP	01-26-82	<.1	< 1	7.40	1050
		<.1	< 1	7.25	1025
		<.1	< 1	7.40	1075
		<.1	< 1	7.35	1100
	05-05-82	<.1	< 1	7.20	950
		<.1	< 1	7.15	1025
		<.1	< 1	7.19	1025
		<.1	< 1	7.20	1050
	08-24-82	<.1	< 1	7.03	1075
		<.1	< 1	7.05	1100
		<.1	< 1	7.10	1125
		<.1	< 1	7.07	1100
	11-16-82	<.1	< 1	7.15	1025
		<.1	< 1	7.15	1000
		<.1	< 1	7.16	1050
		<.1	< 1	7.14	1050
	Mean	<.1	< 1	7.19	1052
	Variance	0	0	0.013	1956

⟁ NVIRONMENT, inc.

June 6, 1983

Fisher Body Elyria Plant
Attn: Mr. Tom Applegate
P.O. Box 4025
Elyria, OH   44036

Enclosed is a report of the monitoring well samples collected
May 13, 1983. On 5-12-83 A.H. Environment personnel pumped
out the four wells. The wells were sampled on 5-13-83. All
samples were taken by Curtis Eldridge and Don Dauch.

Well #	(Pump Out Data) Water Level*	Date/Time	(Sample Data) Water Level	Date/Time
P-1	7'10"	5-12-83/11:08	12'4"	5-13-83/10:24
P-2	3'0"	5-12-83/10:35	3'6"	5-13-83/11:00
P-5	7'11"	5-12-83/10:45	8'4"	5-13-83/10:36
P-6	3'8"	5-12-83/10:20	4'7"	5-13-83/10:51

*Water level is distance below top of well pipe.

All samples were iced immediately after collection and transported
in the ice chests. Samples were received at our lab within 2 hours
of collection. The following analysis were performed upon arrival:
pH, specific conductivity, TOC, TOH, sulfate and chloride. A Second
fraction (4 liters) was adjusted to a pH of 2 with HNO_3 and later
used for the metal analysis. All metals were completed within 11
days. Attached is a listing of the analysis results for each par-
ameter and its detection level. In addition one QA/QC set of
samples (in addition to normal calibration samples) was ran for
each of the parameters. All values are listed in mg/L except
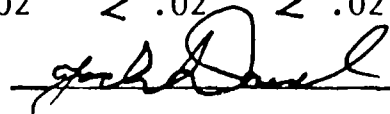where otherwise specified.

Sincerely yours,

Jack Dauch

JD/nl

Parameter	Sensitivity	P-1	P-2	P-5	P-6	QC Actual/reported
Zinc	.02	< .02	< .02	< .02	< .02	.10/.10
Nickel	.02	< .02	< .02	< .02	< .02	.10/.10
Copper	.02	< .02	< .02	< .02	< .02	.10/.10
Chloride	10	< 10	< 10	< 10	< 10	100/98
Iron	0.1	< 0.10	< 0.10	< 0.10	< 0.10	10/9.9
Manganese	0.02	.38	.23	.24	.44	.100/.101
Phenols	.005	< .005	< .005	< .005	< .005	.015/.015
Sodium	.02	2.84	2.76	2.49	1.78	1.00/.99
Sulfate	10	295	184	220	198	250/255
pH	.05 pH units	6.91	7.30	7.02	7.11	7.02/7.02
		6.91	7.29	7.02	7.12	7.41/7.41
		6.93	7.29	7.03	7.13	
		6.92	7.29	7.01	7.12	
Spec. Cond. at 1000 umhos ± 35		1600	1200	1275	1000	
		1650	1250	1275	1025	1413/1408
at 1600 umhos ± 50		1575	1175	1300	1050	
		1600	1175	1300	1050	
T.O.C.	1	< 1	< 1	< 1	< 1	2.00/2.03
		< 1	< 1	< 1	< 1	
		< 1	< 1	< 1	< 1	10.0/9.90
		< 1	< 1	< 1	< 1	
T.O.H. (Halogen)	0.1	< .1	< .1	< .1	< .1	.25/.23
		< .1	< .1	< .1	< .1	
		< .1	< .1	< .1	< .1	
		< .1	< .1	< .1	< .1	
Hexavalent Chromium	.02	< .02	< .02	< .02	< .02	.35/.33
Trivalent Chromium	.02	< .02	< .02	< .02	< .02	.85/.85

Analysis Performed by A.H. Environment, Inc. _____

◉ ⒜⒣ NVIRONMENT, inc.

Dec. 13, 1983

Fisher Body Elyria Plant
Attn: Mr. Tom Applegate
Box 4026
Elyria, OH   44036

Enclosed is a report of the monitoring well samples collected
Nov. 23, 1983. On 11-21-83 A.H. Environment personnel pumped
out the four wells. The wells were sampled on 11-23-83. All
samples were taken by Curtis Eldridge and Marc Corbett.

Well #	(Pump Out Data) Water Level*	Date/Time	(Sample Data) Water Level	Date/Time
P-1	9'12"	11-21-83/11:00	11'2"	11-23-83/11:00
P-2	3'8"	11-21-83/11:30	3'11"	11-23-83/11:00
P-5	7'8"	11-21-83/10:50	8'4"	11-23-83/11:15
P-6	6'1"	11-21-83/10:25	5'2"	11-23-83/11:40

*Water level is distance below top of well pipe.

All samples were iced immediately after collection and transported
in the ice chests. Samples were received at our lab within 2 hours
of collection. The following analysis were performed upon arrival:
pH, specific conductivity, TOC,TOH, sulfate and chloride. A second
fraction (4 liters) was adjusted to a pH of 2 with HNO_3 and later
used for the metal analysis. All metals were completed within 11
days. Attached is a listing of the analysis results for each par-
ameter and its detection level. In addition one QA/QC wet or sam-
ples (in addition to normal calibration samples) was ran for each
of the parameters. All values are listed in mg/L except where
otherwise specified.

Sincerely yours,

Jack Dauch

JD/nl

Parameter	Sensitivity	P-1	P-2	P-5	P-6	QC Actual/reported
Zinc	.02	0.33	<.02	0.29	<.02	.10/.10
Nickel	.02	<.02	<.02	<.02	<.02	.10/.10
Copper	.02	<.02	<.02	<.02	<.02	.10/.10
Chloride	10	<10	<10	<10	<10	100/98
Iron	0.1	<0.10	<0.10	<0.10	<0.10	10/9.9
Manganese	0.02	.82	.58	.29	.65	.100/.101
Phenols	.005	<.005	<.005	<.005	<.005	.015/.015
Sodium	.02	3.17	2.99	2.61	1.44	1.00/.99
Sulfate	10	325	250	230	215	250/255
pH	.05 pH units	6.91	6.95	6.82	6.91	7.02/7.02
		6.91	7.09	6.87	6.92	7.41/7.41
		6.96	7.09	6.80	6.93	
		6.93	7.03	6.81	6.90	
Spec. Cond. at 1000 umhos $\pm$ 35		1500	1300	1275	1200	
		1550	1350	1275	1200	1413/1408
at 1600 umhos $\pm$ 50		1555	1255	1200	1000	
		1600	1275	1250	1000	
T.O.C.	1	<1	<1	<1	<1	2.00/2.03
		<1	<1	<1	<1	
		<1	<1	<1	<1	10.0/9.90
		<1	<1	<1	<1	
T.O.H. (Halogen)	0.1	<.1	<.1	<.1	<.1	.25/.23
		<.1	<.1	<.1	<.1	
		<.1	<.1	<.1	<.1	
		<.1	<.1	<.1	<.1	
Hexavalent Chromium	.02	<.02	<.02	<.02	<.02	.35/.33
Trivalent Chromium	.02	<.02	<.02	<.02	<.02	.85/.85

Analysis Performed by A.H. Environment, Inc.

Fisher Body Division
General Motors Corporation
PO Box 4025
Elyria, Ohio 44036

Date: April 30, 1984

Project Number: 7269

Attn: Mr. Tom Applegate

Samples Received: 4/18/84

ERG-Cleve Sample ID	Elyria Sample ID	Conductivity(µhmos/cm)	pH(S.U.)
24,674A	P-1	660	10.8
B		670	10.8
C		670	10.8
D		670	10.8
24,675A	P-6	760	7.5
B		770	7.5
C		780	7.5
D		780	7.5
24,676A	P-2	860	7.0
B		860	7.1
C		870	7.1
D		860	7.1
24,677A	P-5	990	10.7
B		1,000	10.7
C		1,000	10.7
D		1,000	10.7

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ory Manager

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WELL	BELOW TOP	P.IZ.M. LVL
P-1	9.17	746.63
P-2	3.04	745.86
P-5	8.50	743.70
P-6	4.17	749.63

[sideways header: MONITOR WELL WATER LEVELS]

General Motors Corporation
Fisher Body Elyria Plant
Murray Ridge Road Entrance
PO Box 4025
Elyria, Ohio 44036

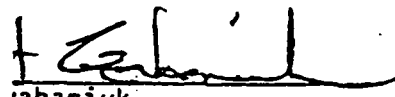Date: May 18, 1984

Project Number: 7351

Attn: Mr. T. Applegate

Samples Received: 5/05/84

ERG-Cleve Sample ID	GM-Elyria Sample ID	Conductivity(µhmos/cm)	pH(S.U.)
24,894A	P-1	1,450	6.8
B		1,450	6.8
C		1,460	6.8
D		1,460	6.8
24,895A	P-2	1,060	7.3
B		1,060	7.3
C		1,050	7.3
D		1,050	7.3
24,896A	P-5	970	7.4
B		970	7.4
C		970	7.5
D		970	7.4
24,897A	P-6	970	7.1
B		970	7.1
C		970	7.1
D		970	7.1

:abaniuk
itory Manager

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5/5/84

MONITOR WELL LEVELS

MONITOR WELL N°	FT BELOW TOP	PIEZ. LVL
P-1	11.75	738.05
P-2	3.08	746.82
P-5	11.33	740.07
P-6 (UP)	4.04	749.76

MONITOR WELL LEVELS
Below
Top
PIEZOMT.
LVL.

Date: June 30, 1984

Project Number: W7457

Results reported in μg/l except where noted.

GROUNDWATER MONITORING
1ST SEMI ANN'L 1984

				Specific Conductance	Total Organic Carbon
P-1	9.17	740.63			
P-2	3.25	745.65	)	1080	6
				930	6
				940	6
P-5	8.25	743.95		940	5
				705	ND (2)
				710	2
				690	3
P-6 up	4.25	749.55		660	2
				890	3
				890	4
		-		890	3
		d	7.6	880	3
25,441	P-6 a		7.3	500	ND (2)
	b		7.2	490	2
	c		7.3	490	2
	d		7.3	500	3

ND- non-detectable: Detection limit shown next to "ND" notation.

General Motors Corporation
Fisher Body Division
PO Box 4025
Elyria, Ohio 44036

Attn: Mr. Tom Applegate

Samples received: May 30, 1984

Date: June 20, 1984

Project Number: V7457

Results reported in ug/l except
where noted.

GROUNDWATER MONITORING
1ST SEMI ANN'L 1984

ERG Cleve Sample ID	GM Elyria Sample ID	pH (S.U.)	Specific Conductance	Total Organic Carbon
25,438	P-1 a	6.8	1080	6
	b	6.8	930	6
	c	6.8	940	6
	d	6.9	940	5
25,439	P-2 a	7.3	705	ND (2)
	b	7.3	710	2
	c	7.3	690	3
	d	7.3	660	2
25,440	P-5 a	7.6	890	3
	b	7.6	890	4
	c	7.6	890	3
	d	7.6	880	3
25,441	P-6 a	7.3	500	ND (2)
	b	7.2	490	2
	c	7.3	490	2
	d	7.3	500	3

ND- non-detectable: Detection limit shown next to "ND" notation.

General Motors Corporation
Fisher Body Division
PO Box 4025
Elyria, Ohio 44036

Attn: Mr. Tom Applegate

Samples Received: 11/08/84

ERG-Cleve Sample ID	GM-Elyria Sample ID	pH(S.U.)	Conductivity (µhmos/cm)	Total Org Carbon			
27,839A	P-1	6.6	1190	7			
B		6.6	1190	7			
C		6.6	1190	8			
D		6.6	1200	8			
27,840A	P-2	7.1	720	ND-2			
B		7.1	725	ND-2			
C		7.1	725	ND-2			
D		7.1	720	ND-2	0.01	ND-0.002	ND-0.002
27,841A	P-5	6.9	1200	4	0.35	ND-0.002	0.033
B		6.9	1200	4	0.29	ND-0.002	0.032
C		6.9	1200	4	0.28	0.002	0.030
D		6.9	1200	4	0.21	ND-0.002	0.039
27,842A	P-6	7.1	640	ND-2	ND-0.01	ND-0.002	ND-0.002
B		7.1	640	ND-2	ND-0.01	ND-0.002	ND-0.002
C		7.1	650	ND-2	ND-0.01	ND-0.002	ND-0.002
D		7.1	650	ND-2	ND-0.01	ND-0.002	ND-0.002

ND-non-detectable. Detection limits are shown next to "ND" notations.

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GW MONIT.
2nd SEMI-ANNL

MONITOR WELL LEVELS   11-7-84

WELL	DEPTH	PIEZO. LVL
P-1	13.08	736.72
P-2	8.58	740.32
P-5	11.33	740.87
P-6 up	12.33	741.47

General Motors Corporation
Fisher Body Division
PO Box 4025
Elyria, Ohio 44036

Attn: Mr. Tom Applegate

Samples Received: 11/08/84

Date: December 27, 1984

Project Number: 8068

Results reported in mg/l
except where noted.

ERG-Cleve Sample ID	GM-Elyria Sample ID	pH(S.U.)	Conductivity (μhmos/cm)	Total Organic Carbon	Organic Chloride	TOTAL ORGANIC HALOGENS Organic Bromide	Organic Iodine
27,839A	P-1	6.6	1190	7	0.04	ND-0.002	0.004
B		6.6	1190	7	0.05	ND-0.002	0.009
C		6.6	1190	8	0.01	0.002	0.002
D		6.6	1200	8	0.02	ND-0.002	0.017
27,840A	P-2	7.1	720	ND-2	ND-0.01	ND-0.002	0.002
B		7.1	725	ND-2	0.01	ND-0.002	ND-0.002
C		7.1	725	ND-2	0.01	ND-0.002	0.003
D		7.1	720	ND-2	0.01	ND-0.002	ND-0.002
27,841A	P-5	6.9	1200	4	0.35	ND-0.002	0.033
B		6.9	1200	4	0.29	ND-0.002	0.032
C		6.9	1200	4	0.28	0.002	0.030
D		6.9	1200	4	0.21	ND-0.002	0.039
27,842A	P-6	7.1	640	ND-2	ND-0.01	ND-0.002	ND-0.002
B		7.1	640	ND-2	ND-0.01	ND-0.002	ND-0.002
C		7.1	650	ND-2	ND-0.01	ND-0.002	ND-0.002
D		7.1	650	ND-2	ND-0.01	ND-0.002	ND-0.002

ND-non-detectable. Detection limits are shown next to "ND" notations.

AFFILIATED ENVIRONMENTAL SERVICES, Inc.

Jan. 22, 1985

Fisher Body Elyria Plant
Attn: Mr. Tom Applegate
P.O. Box 4025
Elyria, OH   44036
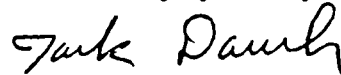
Enclosed is a report of the monitoring well samples collected
Jan. 14, 1985. On 1-11-85 AES personnel pumped out the four
wells. The wells were sampled on 1-14-85. All samples were
taken by R. Conway and D. Didion.

Well #	(Pump Out Data) Water Level*	Date/Time	(Sample Data) Water Level	Date/Time
P-1	9'4"	1-11/10:43	9'3"	1-14/11:15
P-2	3'8"	1-11/11:17	3'2"	1-14/10:46
P-5	8'9"	1-11/10:22	8'4"	1-14/11:00

   *Water level is distance below top of well pipe.

All samples were iced immediately after collection and trans-
ported in the ice chests. Samples were received at out lab
within 2 hours of collection. The following analysis were
performed upon arrival: pH, specific conductivity, TOC, TOX.
Attached is a listing of the analysis results for each parameter
and its detection level. In addition one QA/QC set of samples
(in addition to normal calibration samples) was ran for each
of the parameters. All values are listed in mg/L except where
otherwise specified.

Sincerely yours,

Jack Dauch

Jack Dauch

DD/nl

Parameter	Sensitivity	Well P-1	Well P-2	Well P-5	QC actual/reported
pH	.05 pH units	6.61	6.85	6.68	7.00/7.01
		6.60	6.84	6.68	7.45/7.45
		6.61	6.83	6.67	
		6.61	6.83	6.67	
Spec. Cond.	at 1000 umhos ± 35	1550	1025	1225	1250/1260
	at 1600 umhos ± 50	1600	1025	1300	
		1600	1050	1300	
		1575	1050	1325	
T.O.C.	1 m/L	<1	1.3	<1	2.00/2.02
		<1	1.4	<1	10.0/9.91
		<1	1.4	<1	
		<1	1.4	<1	
T.O.X. (Halogen)	0.1	<.1	<.1	<.1	.25/.24
		<.1	<.1	<.1	
		<.1	<.1	<.1	
		<.1	<.1	<.1	

Analysis performed by Affiliated Environmental Services, Inc.

Jack Dauch
Jack Dauch

General Motors Corporation
Fisher Body Division
PO Box 4025
Elyria, Ohio 44036

Attn: Mr. Tom Applegate

Samples Received: 6/28/85

Date: July 31, 1985

Project Number: 8976

Results reported in mg/l
except where noted.

GROUNDWATER

ERG-Cleve Sample ID	GM-Elyria Sample ID	pH (S.U.)	Conductivity (µhmos/cm)	Total Organic Carbon	Organic Chloride	Organic Bromide	Organic Iodide	Chloride	Iron	Zinc
30,896A	P-1	7.4	810	6	0.35	ND-0.01	0.02	120	1.7	0.23
B		7.4	800	4	0.46	ND-0.01	0.01	---	---	----
C		7.4	810	5	0.65	ND-0.01	0.02	---	---	----
D		7.4	800	5	0.45	ND-0.01	0.02	---	---	----
30,897A	P-2	7.2	640	2	0.02	ND-0.01	ND-0.01	2.6	1.5	0.037
B		7.2	650	<2	0.28	ND-0.01	ND-0.01	---	---	----
C		7.2	650	2	0.14	ND-0.01	ND-0.01	---	---	----
D		7.2	650	<2	0.10	ND-0.01	ND-0.01	---	---	----
30,898A	P-5	6.7	820	2	0.13	ND-0.01	0.01	0.88	1.4	0.043
B		6.7	820	3	0.07	ND-0.01	0.01	---	---	----
C		6.7	840	3	0.15	ND-0.01	0.01	---	---	----
D		6.7	820	2	0.16	ND-0.01	0.02	---	---	----
30,899A	P-6	7.2	590	ND-2	0.18	ND-0.01	ND-0.01	2.6	3.5	0.028
B		7.2	600	ND-2	0.26	ND-0.01	ND-0.01	---	---	----
C		7.2	590	ND-2	0.14	ND-0.01	ND-0.01	---	---	----
D		7.2	600	<2	0.14	ND-0.01	ND-0.01	---	---	----

ND=non-detectable. Detection limits are shown next to "ND" notations.

ANALYTICAL REPORT

ENVIRONMENTAL RESEARCH GROUP, INC.

Project: V9751
Report Date: 02-03-86

7777 EXCHANGE STREET
CLEVELAND, OH 44125 (216) 447-0790

Client P.O. ELY 630007
Report: 16586

Samples Recvd: 12-19-85
Refer Questions To:
JOHN PALMER

Client:
GENERAL MOTORS CORPORATION
FISHER BODY DIVISION
PO BOX 4025
ELYRIA, OH 44036
Attention: TOM APPLEGATE

Approved: _____

***
Residual Samples Will Be Held
TWO WEEKS
***

Client I.D.:   P-1 A
ERG Sample No.:   12/142827
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ALUMINUM, TOTAL	14.6	mg/L
BARIUM, TOTAL	1.9	mg/L
ORGANIC CARBON, TOTAL	12	mg/L
CHLORIDE	41	mg/L
HEXAVALENT CHROMIUM	ND (0.02)	mg/L
AVERAGE OF DUPLICATE RUNS		
CHROMIUM, TOTAL	0.05	mg/L
TRIVALENT CHROMIUM	0.05	mg/L
SPECIFIC CONDUCTANCE	1500	umho/cm
COPPER, TOTAL	0.10	mg/L
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
IRON, TOTAL	22	mg/L
LEAD, TOTAL	0.09	mg/L
MAGNESIUM, TOTAL	50	mg/L
MANGANESE, TOTAL	0.46	mg/L
NICKEL, TOTAL	<0.05	mg/L
PHENOLS	0.22	mg/L
AVERAGE OF DUPLICATE RUNS		
SODIUM	6.9	mg/L
SULFATE	310	mg/L
ZINC	0.13	mg/L
pH	7.2	S.U.

Comments: DEPTH TO WATER 10'4"

ANALYTICAL REPORT

ENVIRONMENTAL RESEARCH GROUP, INC.

Project: V9751
Report Date: 02-03-86

Client I.D.: P-1 B
ERG Sample No.: 12/142828
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	11	mg/L
SPECIFIC CONDUCTANCE	1600	umho/cm
AVERAGE OF DUPLICATE RUNS		
HALOSCAN - T		
ORGANIC CHLORINE	0.03	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
pH	7.2	S.U.

Client I.D.: P-1 C
ERG Sample No.: 12/142829
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	10	mg/L
SPECIFIC CONDUCTANCE	1600	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
pH	7.2	S.U.

Client I.D.: P-1 D
ERG Sample No.: 12/142830
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	10	mg/L
SPECIFIC CONDUCTANCE	1600	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	0.03	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
pH	7.2	S.U.
AVERAGE OF DUPLICATE RUNS		

Client I.D.: P-2 A
ERG Sample No.: 12/142831
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ALUMINUM, TOTAL	0.8	mg/L
BARIUM, TOTAL	0.78	mg/L

ANALYTICAL REPORT

erg

ENVIRONMENTAL RESEARCH GROUP, INC.

Client I.D.:   P-2 A
ERG Sample No.:   12/142831
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	7	mg/L
CHLORIDE	29	mg/L
HEXAVALENT CHROMIUM	ND (0.02)	mg/L
CHROMIUM, TOTAL	<0.02	mg/L
TRIVALENT CHROMIUM	<0.02	mg/L
SPECIFIC CONDUCTANCE	1100	umho/cm
COPPER, TOTAL	<0.02	mg/L
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	ND (0.01)	mg/L
IRON, TOTAL	1.5	mg/L
LEAD, TOTAL	0.14	mg/L
MAGNESIUM, TOTAL	22	mg/L
MANGANESE, TOTAL	0.61	mg/L
NICKEL, TOTAL	<0.05	mg/L
PHENOLS	ND (0.01)	mg/L

AVERAGE OF DUPLICATE RUNS

SODIUM	78	mg/L
SULFATE	180	mg/L
ZINC	0.02	mg/L
pH	7.4	S.U.

Comments: DEPTH TO WATER 4'6"

Client I.D.:   P-2 B
ERG Sample No.:   12/142832
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	6	mg/L
SPECIFIC CONDUCTANCE	1000	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	ND (0.01)	mg/L
pH	7.4	S.U.

ANALYTICAL REPORT

ENVIRONMENTAL RESEARCH GROUP, INC.

Project: V9751
Report Date: 02-03-86

Client I.D.:   P-2 C
ERG Sample No.:   12/142833
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	5	mg/L
SPECIFIC CONDUCTANCE	1000	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	ND (0.01)	mg/L
pH	7.5	S.U.

Client I.D.:   P-2 D
ERG Sample No.:   12/142834
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	6	mg/L
SPECIFIC CONDUCTANCE	1000	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	ND (0.01)	mg/L
pH	7.5	S.U.

Client I.D.:   P-5 A
ERG Sample No.:   12/142835
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ALUMINUM, TOTAL	0.4	mg/L
BARIUM, TOTAL	1.5	mg/L
ORGANIC CARBON, TOTAL	9	mg/L
CHLORIDE	110	mg/L
HEXAVALENT CHROMIUM	ND (0.02)	mg/L
CHROMIUM, TOTAL	0.02	mg/L
TRIVALENT CHROMIUM	0.02	mg/L
SPECIFIC CONDUCTANCE	1500	umho/cm
COPPER, TOTAL	0.07	mg/L
HALOSCAN - T		
ORGANIC CHLORINE	0.26	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
IRON, TOTAL	0.87	mg/L
LEAD, TOTAL	<0.05	mg/L
MAGNESIUM, TOTAL	32	mg/L
MANGANESE, TOTAL	0.25	mg/L
NICKEL, TOTAL	<0.05	mg/L
PHENOLS	0.15	mg/L

erg
ANALYTICAL REPORT
ENVIRONMENTAL RESEARCH GROUP, INC.

Project: V9751
Report Date: 02-03-86

Client I.D.: P-5 A
ERG Sample No.: 12/142835
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
SODIUM	86	mg/L
SULFATE	270	mg/L
ZINC	0.15	mg/L
pH	7.6	S. U.

Comments: DEPTH TO WATER 9'6"

Client I.D.: P-5 B
ERG Sample No.: 12/142836
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	7	mg/L
AVERAGE OF DUPLICATE RUNS		
SPECIFIC CONDUCTANCE	1500	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	0.29	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
pH	7.4	S. U.

Client I.D.: P-5 C
ERG Sample No.: 12/142837
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	10	mg/L
SPECIFIC CONDUCTANCE	1500	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	0.24	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
pH	7.6	S. U.

Client I.D.: P-5 D
ERG Sample No.: 12/142838
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	10	mg/L
SPECIFIC CONDUCTANCE	1500	umho/cm

ANALYTICAL REPORT

ENVIRONMENTAL RESEARCH GROUP, INC.

Project: V9751
Report Date: 02-03-86

Client I.D.:   P-5 D
ERG Sample No.:   12/142838
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
HALOSCAN - T		
ORGANIC CHLORINE	0.24	mg/L
ORGANIC BROMINE	ND (0.01)	mg/L
ORGANIC IODINE	0.02	mg/L
pH	7.6	S.U.

Client I.D.:   P-6 A
ERG Sample No.:   12/142839
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ALUMINUM, TOTAL	0.6	mg/L
BARIUM, TOTAL	1.1	mg/L
ORGANIC CARBON, TOTAL	7	mg/L
CHLORIDE	4	mg/L
AVERAGE OF DUPLICATE RUNS		
HEXAVALENT CHROMIUM	ND (0.02)	mg/L
CHROMIUM, TOTAL	<0.02	mg/L
TRIVALENT CHROMIUM	<0.02	mg/L
SPECIFIC CONDUCTANCE	980	umho/cm
AVERAGE OF DUPLICATE RUNS		
COPPER, TOTAL	<0.02	mg/L
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	0.02	mg/L
ORGANIC IODINE	<0.01	mg/L
IRON, TOTAL	0.78	mg/L
LEAD, TOTAL	0.05	mg/L
MAGNESIUM, TOTAL	34	mg/L
MANGANESE, TOTAL	0.17	mg/L
NICKEL, TOTAL	<0.05	mg/L
PHENOLS	0.10	mg/L
SODIUM	7.5	mg/L
SULFATE	200	mg/L
ZINC	0.03	mg/L
pH	7.4	S.U.

Comments: DEPTH TO WATER 5'9"

ANALYTICAL REPORT

ENVIRONMENTAL RESEARCH GROUP, INC.

Project: V9751
Report Date: 02-03-86

Client I.D.:   P-6 B
ERG Sample No.: 12/142840
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	6	mg/L
SPECIFIC CONDUCTANCE	980	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	0.02	mg/L
ORGANIC IODINE	<0.01	mg/L
pH	7.3	S.U.

Client I.D.:   P-6 C
ERG Sample No.: 12/142841
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	6	mg/L
SPECIFIC CONDUCTANCE	980	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	0.02	mg/L
ORGANIC IODINE	<0.01	mg/L
pH	7.3	S.U.

Client I.D.:   P-6 D
ERG Sample No.: 12/142842
Matrix: GROUND WATER
Date Sampled: 12-18-85

Parameter	Result	Units
ORGANIC CARBON, TOTAL	8	mg/L
SPECIFIC CONDUCTANCE	980	umho/cm
HALOSCAN - T		
ORGANIC CHLORINE	<0.01	mg/L
ORGANIC BROMINE	0.03	mg/L
ORGANIC IODINE	<0.01	mg/L
pH	7.4	S.U.

AVERAGE OF DUPLICATE RUNS

SD-Sample damaged
FR-See field report for result
SR-See attached report
NA-Result not applicable to test

ND-Nondetected, Detection limit in ()
<-Positive result at an unquantifiable
concentration below indicated level

Thank you for your business.   Page 7   Last Page

GROUNDWATER MONITORING ANALYSIS   2-27-86

SAMPLES DATED   12-18-85   — t·TEST —   FISHER GUIDE
REPORT DATED   2-3-86   REC'D 2-12-86   ELYRIA, OH

1982 BACKGROUND DATA (UPGRADIENT) P-6

		pH	SPEC. COND.	TOC	TOH	ELEV (MSL)
	$\bar{X}$	7.19	1052	<1	<0.1	
	S^2	0.013	1956	0	0	
	S	0.114	44.22	0	0	
DEC. 85						
P-1	$\bar{X}$	7.20	1575	10.75	0.04	10'-4
DN	S^2	0.00	2500	0.92	0.0003	(739.5)
	t^*	0.35	19.13	20.33	-6.93	
	t_c	2.95	4.22	4.54	4.54	
	SIGNIF.	0.12	4.53	4.46	-1.53	
P-2	$\bar{X}$	7.45	1025	6.0	0.00	4'-6
DN	S^2	0.0033	2500	0.67	0.00	(744.4)
	t^*	6.43	-0.99	12.22	INDET	
	t_c	4.41	4.22	4.54	—	
	SIGNIF.	1.46	-0.23	2.69	NO	
P-5	$\bar{X}$	7.50 7.55	1500	9.00	0.28	9'-6
DN	S^2	0.013 .010	0	2.00	0.00052	(742.7)
	t^*	4.86 6.25	40.52	11.31	15.21	
	t_c	5.26 5.10	2.60	4.54	4.54	
	SIGNIF.	0.92 1.22	15.57	2.49	3.35	
P-6	$\bar{X}$	7.35	980	6.75	0.02	5'-9
UP	S^2	0.0033	0	0.92	0.000025	(748.0)
	t^*	3.95	-6.51	11.99	-32.00	
	t_c	4.41	2.60	4.54	4.54	
	SIGNIF.	0.90	-2.50	2.64	-7.05	

_____ = STATISTICALLY SIGNIFICANT CHANGE from BASELINE

Laboratory Analysis Report
For

General Motors Corporation
Elyria, Ohio

Analyses

Samples Received: 4/14/86
Report Date: 5/05/86

Source	Sample[4] Point 9	Sample[5] Point 10	Sample[4] Point 11	Sample[1] Point 12	Sample[5] Point 13
Log No. 86-	03523	03524	03525	03526	03527
Date Collected	4/8/86	4/8/86	4/8/86	4/8/86	4/8/86
pH	7.9	8.0	7.7	7.3	7.9
Specific Conductance, µmhos/cm	796	632	817	1,583	634
Total Organic Carbon, mg/L C	33	31	34	30	30
Total Organic Halogen, mg/L Cl	0.018	0.008	0.014	0.018	0.005

Source	Sample[1] Point 14	Sample[5] Point 15	Sample[1] Point 16	Sample[3] Point 17	Sample[3] Point 18
Log No. 86-	03528	03529	03530	03531	03532
Date Collected	4/8/86	4/8/86	4/8/86	4/8/86	4/8/86
pH	7.4	7.9	7.2	7.4	7.5
Specific Conductance, µmhos/cm	1,542	646	1,643	1,475	1,496
Total Organic Carbon, mg/L C	25	27	24	26	26
Total Organic Halogen, mg/L Cl	0.014	0.005	0.020	0.015	0.018

[1] Sample collected from piezometer P-1
[2] Sample collected from piezometer P-2
[3] Sample collected from piezometer P-5
[4] Sample collected from piezometer P-6
[5] Sample collected from piezometer OW-1

3128-91

- Unless otherwise noted, analyses are in accordance with the methods and procedures outlined and approved by the Environmental Protection Agency and conform to quality assurance protocol.
- "Less-than" (<) values are indicative of the detection limit.

A Division Of

The Chester Engineers
P O Box 9358
Pittsburgh
Pennsylvania 15225
Phone. (412) 269-5700

Laboratory Analysis Report
For

General Motors Corporation
Elyria, Ohio

Analyses

Samples Received: 4/14/86
Report Date: 5/05/86

Source	Sample[5] Point 19	Sample[3] Point 20	Sample[2] Point 1	Sample[1] Point 2	Sample[2] Point 3
Log No. 86-	03513	03514	03515	03516	03517
Date Collected	4/8/86	4/8/86	4/8/86	4/8/86	4/8/86
pH	8.0	7.6	7.8	7.3	7.9
Specific Conductance, μmhos/cm	631	1,439	921	1,532	919
Total Organic Carbon, mg/L C	32	26	36	28	38
Total Organic Halogen, mg/L Cl	0.005	0.012	0.010	0.018	0.009

Source	Sample[2] Point 4	Sample[2] Point 5	Sample[3] Point 6	Sample[4] Point 7	Sample[4] Point 8
Log No. 86-	03518	03519	03520	03521	03522
Date Collected	4/8/86	4/8/86	4/8/86	4/8/86	4/8/86
pH	8.1	8.1	7.6	7.7	7.9
Specific Conductance, μmhos/cm	896	917	1,453	841	784
Total Organic Carbon, mg/L C	32	40	27	28	32
Total Organic Halogen, mg/L Cl	0.009	0.010	0.012	0.013	0.015

[1]Sample collected from piezometer P-1
[2]Sample collected from piezometer P-2
[3]Sample collected from piezometer P-5
[4]Sample collected from piezometer P-6
[5]Sample collected from piezometer OW-1

3128-91

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The Chester Engineers

P O Box 9356
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Phone (412) 269-5700

Laboratory Analysis Report
For

General Motors Corporation
Elyria, Ohio

Samples Received: 6/20/86

Report Date: 7/11/86

Analyses

Source	Sample[2] Point #1	Sample[1] Point #2	Sample[2] Point #3	Sample[2] Point #4	Sample[2] Point #5
Log No. 86-	05641	05642	05643	05644	05645
pH	8.0	7.1	8.1	8.0	8.1
Specific Conductance, μmhos/cm	1,058	1,626	1,026	918	918
Total Organic Carbon, mg/L C	7.5	7.0	6.0	6.5	5.5
Total Organic Halogen, mg/L Cl	0.012	0.017	0.018	0.028	0.021

Source	Sample[3] Point #6	Sample[4] Point #7	Sample[4] Point #8	Sample[4] Point #9	Sample[5] Point #10
Log No. 86-	05656	05657	05658	05659	05660
pH	7.4	7.8	7.6	7.8	8.1
Specific Conductance, μmhos/cm	1,564	876	926	747	690
Total Organic Carbon, mg/L C	5.0	5.5	6.5	8.0	7.0
Total Organic Halogen, mg/L Cl	0.008	0.023	0.020	0.014	0.007

[1] Sample collected from piezometer P-1
[2] Sample collected from piezometer P-2
[3] Sample collected from piezometer P-5
[4] Sample collected from piezometer P-6
[5] Sample collected from piezometer OW-1

3128-91

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Laboratory Analysis Report
For

General Motors Corporation
Elyria, Ohio

Samples Received: 6/20/86
Report Date: 7/11/86

Analyses

Source	Sample[4] Point #11	Sample[1] Point #12	Sample[5] Point #13	Sample[1] Point #14	Sample[5] Point #15
Log No. 86-	05651	05652	05653	05654	05655
pH	7.3	7.6	7.8	7.1	8.0
Specific Conductance, µmhos/cm	921	1,396	748	1,646	691
Total Organic Carbon, mg/L C	8.0	8.5	6.0	9.0	12
Total Organic Halogen, mg/L Cl	0.018	0.017	0.018	0.030	0.015

Source	Sample[1] Point #16	Sample[3] Point #17	Sample[3] Point #18	Sample[5] Point #19	Sample[3] Point #20
Log No. 86-	05646	05647	05648	05649	05650
pH	7.1	7.7	7.8	8.0	7.4
Specific Conductance, µmhos/cm	1,646	1,483	1,442	833	1,559
Total Organic Carbon, mg/L C	12	20	16	10	12
Total Organic Halogen, mg/L Cl	0.027	0.030	0.029	0.007	0.023

[1] Sample collected from piezometer P-1
[2] Sample collected from piezometer P-2
[3] Sample collected from piezometer P-5
[4] Sample collected from piezometer P-6
[5] Sample collected from piezometer OW-1

3128-91

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Laboratory Analysis Report
For

General Motors Corporation
Elyria, Ohio

Samples Received: 9/06/86
Report Date: 9/17/86

Analyses

Source	Sample[2] Point-1	Sample[1] Point-2	Sample[2] Point-3	Sample[2] Point-4	Sample[2] Point-5
Log No. 86-	07825	07826	07827	07828	07829
pH	7.9	7.7	7.7	7.9	7.4
Specific Conductance, μmhos/cm	1,060	1,693	1,042	1,052	1,063
Total Organic Carbon, mg/L C	8.0	7.8	4.5	5.0	5.0
Total Organic Halogen, mg/L Cl	0.013	0.019	0.016	0.021	0.006

Source	Sample[3] Point-6	Sample[4] Point-7	Sample[4] Point-8	Sample[4] Point-9	Sample[5] Point-10
Log No. 86-	07830	07831	07832	07833	07834
pH	7.5	7.5	7.6	7.5	7.9
Specific Conductance, μmhos/cm	1,596	980	1,000	977	643
Total Organic Carbon, mg/L C	8.5	10	8.0	9.5	4.5
Total Organic Halogen, mg/L Cl	0.019	0.016	0.018	0.015	0.019

[1]Sample collected from piezometer P-1

[2]Sample collected from piezometer P-2

[3]Sample collected from piezometer P-5

[4]Sample collected from piezometer P-6

[5]Sample collected from piezometer OW-1

3128-81

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Phone (412) 269-5700

Laboratory Analysis Report
For

General Motors Corporation
Elyria, Ohio

Samples Received: 9/06/86   Analyses
Report Date: 9/17/86

Source	Sample[5] Point-11	Sample[1] Point-12	Sample[5] Point-13	Sample[1] Point-14	Sample[5] Point-15
Log No. 86-	07835	07836	07837	07838	07839
pH	7.8	7.1	7.2	7.0	7.9
Specific Conductance, μmhos/cm	941	1,706	646	644	636
Total Organic Carbon, mg/L C	8.6	8.0	5.0	8.5	5.0
Total Organic Halogen, mg/L Cl	0.009	0.019	0.008	0.012	0.008

Source	Sample[1] Point-16	Sample[3] Point-17	Sample[3] Point-18	Sample[5] Point-19	Sample[3] Point-20
Log No. 86-	07840	07841	07842	07843	07844
pH	7.3	7.5	7.4	7.8	7.3
Specific Conductance, μmhos/cm	1,706	1,587	1,579	650	1,589
Total Organic Carbon, mg/L C	7.0	5.2	8.2	6.0	8.0
Total Organic Halogen, mg/L Cl	0.010	0.030	0.023	0.010	0.019

[1] Sample collected from piezometer P-1

[2] Sample collected from piezometer P-2

[3] Sample collected from piezometer P-5

[4] Sample collected from piezometer P-6

[5] Sample collected from piezometer OW-1

3128-91

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ATTACHMENT 2

SLUG TEST DATA REDUCTION TECHNIQUES

A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells

HERMAN BOUWER AND R. C. RICE

U.S. Water Conservation Laboratory, Agricultural Research Service, U.S Department of Agriculture, Phoenix, Arizona Technical Conservation Center

A procedure is presented for calculating the hydraulic conductivity of an aquifer near a well from the rate of rise of the water level in the well after a certain volume of water is suddenly removed. The calculation is based on the Thiem equation of steady state flow to a well. The effective radius R_e, over which the head difference between the equilibrium water table in the aquifer and the water level in the well is dissipated was evaluated with a resistance network analog for a wide range of system geometries. An empirical equation relating R_e to the geometry of the well and aquifer was derived. The technique is applicable to completely or partially penetrating wells in unconfined aquifers. It can also be used for confined aquifers that receive water from the upper confining layer. The method's results are compatible with those obtained by other techniques for overlapping geometries.

With the slug test the hydraulic conductivity or transmissibility of an aquifer is determined from the rate of rise of the water level in a well after a certain volume or 'slug' of water is suddenly removed from the well. The slug test is simpler and quicker than the Theis pumping test because observation wells and pumping the well are not needed. With the slug test the portion of the aquifer sampled for hydraulic conductivity is smaller than that for the pumping test even though with the latter, most of the head loss also occurs within a relatively small distance of the pumped well and the resulting transmissibility primarily reflects the aquifer conditions near the pumped well.

Essentially instantaneous lowering of the water level in a well ... be achieved by quickly removing water with a bailer or by partially or completely submerging an object in the water, letting the water level reach equilibrium, and then quickly removing the object. If the aquifer is very permeable, the water level in the well may rise very rapidly. Such rapid rises can be measured with sensitive pressure transducers and fast-response strip chart recorders or x-y plotters. Also it may be possible to isolate portions of the perforated or screened section of the well with special packers for the slug test. This ... reduces the inflow and hence the rate of rise of the water ... in the well, but it also makes it possible to determine the vertical distribution of the hydraulic conductivity. Special packer techniques may have to be developed to obtain a good seal, especially for rough casings or perforations. Effective sealing may be achieved with relatively long sections of inflatable stoppers or tubing. The use of long sections of these materials would also reduce leakage flow from the rest of the well to the isolated section between packers. This flow can occur through gravel envelopes or other permeable zones surrounding the casing. Sections of inflatable tubing may have to be ... enough to block off the entire part of the well not used for the slug test. High inflation pressures should be used to minimize volume changes in the tubing due to changing water pressures in the isolated section when the head is lowered.

So far, solutions for the slug test have been developed only for completely penetrating wells in confined aquifers. *Cooper et al.* [1967] derived an equation for the rise or fall of the water level in a well after sudden lowering or raising, respectively. Their equation was based on nonsteady flow to a pumped

completely penetrating well, and the solution was expressed as a series of 'type curves' against which observed rates of water level rises were matched. Values for the transmissibility and storage coefficient were then evaluated from the curve parameter and horizontal-scale position of the type curve showing the best fit with the experimental data. *Skibitzke* [1958] developed an equation for calculating transmissibility from the recovery of the water level in a well that was repeatedly bailed. The technique is limited to wells in confined aquifers with sufficiently shallow water levels to permit short time intervals between bailing cycles [*Lohman*, 1972].

To use the slug test for partially penetrating or partially perforated wells in confined or unconfined aquifers, some solutions developed for the auger hole and piezometer techniques to measure soil hydraulic conductivity [*Bouwer and Jackson*, 1974] may be employed. However, the geometry of most groundwater wells is outside the range in geometry covered by the existing equations or tables for the auger hole or piezometer. For this reason, theory and equations are presented in this paper for slug tests on partially or completely penetrating wells in unconfined aquifers. The wells may be partially or completely perforated, screened, or otherwise open along their periphery. While the solutions are developed for unconfined aquifers, they may also be used for slug tests on wells in confined aquifers if water enters the aquifer from the upper confining layer through compression or leakage.

THEORY

Geometry and symbols of a well in an unconfined aquifer are shown in Figure 1. For the slug test the water level in the well is suddenly lowered, and the rate of rise of the water level is measured. The flow into the well at a particular value of y can be calculated by modifying the Thiem equation to

$$Q = 2\pi K L \frac{y}{\ln(R_e/r_w)} \qquad (1)$$

where Q is the flow into the well (length^3/time), K is the hydraulic conductivity of the aquifer (length/time), L is the height of the portion of well through which water enters (height of screen or perforated zone or of uncased portion of well), y is the vertical distance between water level in well and equilibrium water table in aquifer, R_e is the effective radius over which y is dissipated, and r_w is the horizontal distance
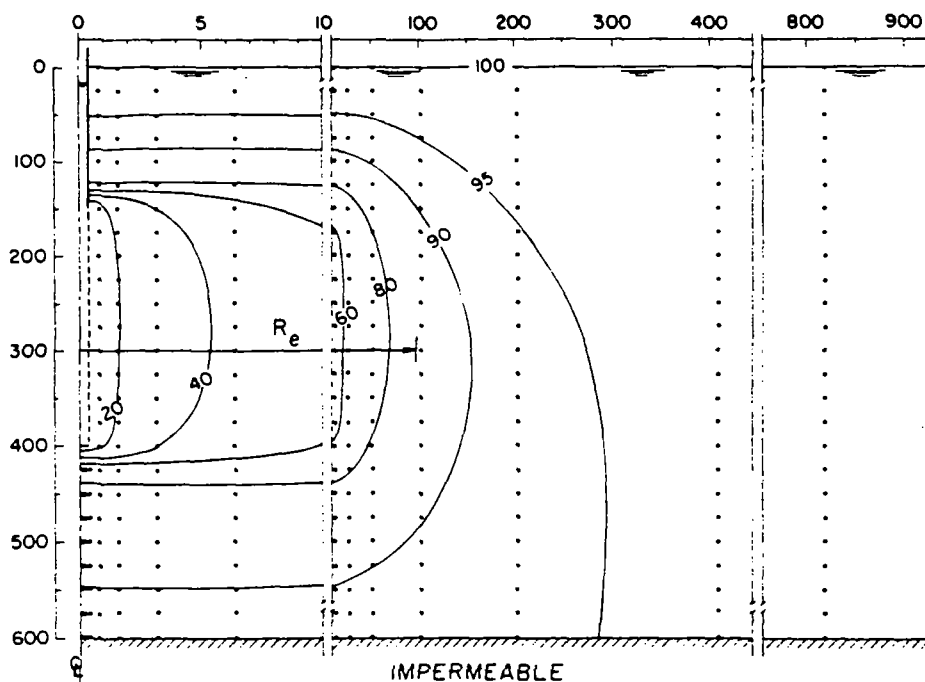
Fig. 2. Node arrangement (dots) for resistance network analog and potential distribution (indicated as percentages on equipotentials) for system with $L/r_u = 625$, $H/r_u = 1000$, and $D/r_u = 1500$. The numbers on the left and at the top of the figure are arbitrary length units (note breaks in horizontal scale).

less than the flow when the layer is taken as being infinitely permeable. The average of the two flows can then be taken as a good estimate of the flow that would occur if the aquifer were represented on the analog as being uniform to infinite depth [Bouwer, 1967]. This average flow was used to calculate R_e for D .

The analog analyses were performed by simulating a system with certain values of r_u, H, and D. The electrical current entering the 'well' was then measured for different values of L, ranging from near H to near 0. This was repeated for other values of r_u, H, and D. The condition where $L = H$ could not be simulated on the analog because it would mean a short between the water table as the source and the well as the sink. The electrical current flow in the analog was converted to volume per day, and ln R_e/r_u was evaluated with (1) for each combination of r_u, H, L, and D used in the analog.

For a given geometry described by r_u, H, and D, the current flow Q_i into the simulated well varied essentially linearly with L and could be described by the equation

$$Q_i = mL + n \qquad (7)$$

Because of the linearity between Q_i and L the results of the analyses could be extrapolated to the condition $L = H$. The values of m in (7) appeared to vary inversely with ln H/r_u. The values of n varied approximately linearly with ln $[(D - H)/r_u]$, the slope A and intercept B in these relations being a function of L/r_u. This enabled the derivation of the following empirical equation relating ln R_e/r_u to the geometry of the system:

$$\ln \frac{R_e}{r_w} = \left[\frac{1.1}{\ln (H/r_w)} + \frac{A + B \ln [(D - H)/r_w]}{L/r_w} \right]^{-1} \qquad (8)$$

In this equation, A and B are dimensionless coefficients that ...ctions of L, r_u, as shown in Figure 3. If $D \gg H$, an ... in D has no measurable effect on ln R_e, r_u. The analog

results indicated that the effective upper limit of ln $[(D - H)/r_u]$ is 6. Thus if D is considered infinity or $(D - H)/r_u$ is so large that ln $[(D - H)/r_u]$ is greater than 6, a value of 6 should still be used for the term ln $[(D - H)/r_u]$ in (8).

If $D = H$, the term ln $[(D - H)/r_u]$ in (8) cannot be used. The analog results indicated that for this condition, which is the case of a fully penetrating well, (8) should be modified to

$$\ln R_e/r_w = \left(\frac{1.1}{\ln (H/r_w)} + \frac{C}{L/r_w} \right)^{-1} \qquad (9)$$

where C is a dimensionless parameter that is a function of L/r_u as shown in Figure 3.

Equations (8) and (9) yield values of ln R_e/r_u that are within 10% of the actual value as evaluated by analog if $L > 0.4H$ and within 25% if $L \ll H$ (for example, $L = 0.1H$).

The analog analyses were performed for wells that were closed at the bottom. Occasionally, however, wells with open bottoms were also simulated. The flow through the bottom appeared to be negligible for all values of r_u and L used in the analyses. If L is not much greater than r_u (for example, $L/r_u \ll 4$), the system geometry approaches that of a piezometer cavity [Bouwer and Jackson, 1974], in which case the bottom flow can be significant. Equations (8) and (9) can also be used to evaluate ln R_e/r_u if a portion of the perforated or otherwise open part of the well is isolated with packers for the slug test.

Equipotentials for the flow system around a partially penetrating, partially perforated well in an unconfined aquifer after lowering the water level in the well are shown in Figure 2. The numbers along the symmetry axis and the water table represent arbitrary length units. The numbers on the equipotentials indicate the potential as a percentage of the total head difference between the water table (100%) and the open portion of the well (0%) shown as a dashed line.

The value of R_e for the case in Figure 2 is 96.7 length units. As shown in the figure, this corresponds approximately to the
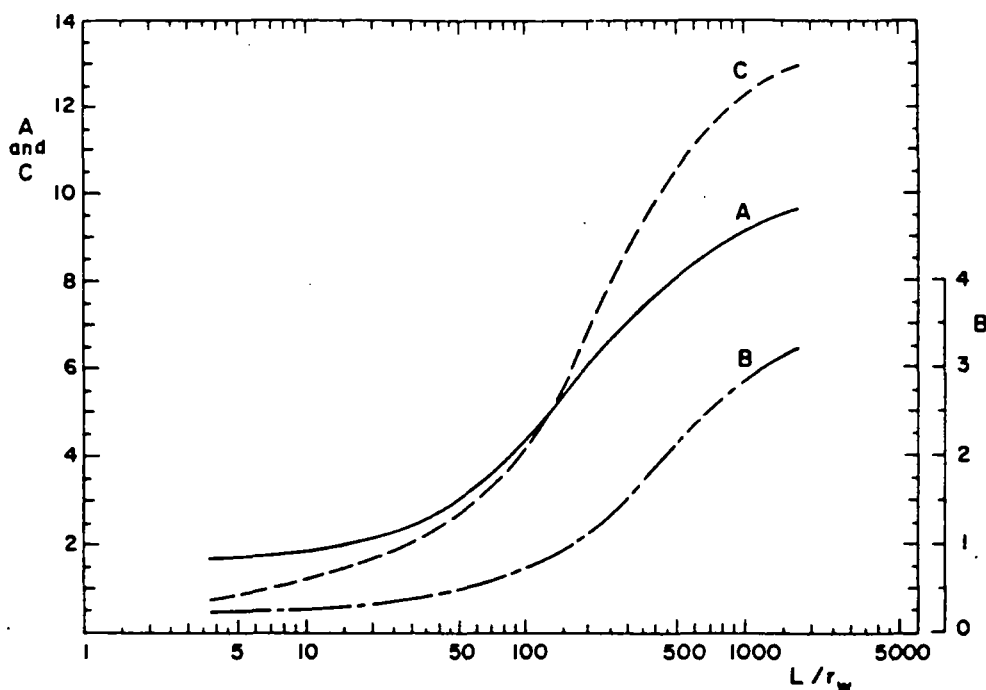
Fig. 3.   Curves relating coefficients A, B, and C to L/r_w.

85% equipotential when R_e is laterally extended from the center of the open portion of the well. Thus most of the head loss in the flow system occurs in a cylinder with radius R_e, which is indicative of the horizontal extent of the portion of the aquifer sampled for K or T. The vertical extent is somewhat greater than L, as indicated by, for example, the 80% equipotential in Figure 2.

To estimate the rate of rise of the water level in a well after it is suddenly lowered, (5) can be written as

$$t = \frac{r_c^2}{2KL} \ln \frac{R_e}{r_w} \ln \frac{y_0}{y_t} \qquad (10)$$

By taking $y_t = 0.9y_0$, (10) reduces to

$$t_{90\%} = 0.0527 \frac{r_c^2}{KL} \ln \frac{R_e}{r_w} \qquad (11)$$

where $t_{90\%}$ is the time that it takes for the water level to rise 90% of the distance to the equilibrium level. By assuming a permeable aquifer with $K = 30$ m/day, a well with $r_c = 0.2$ m and $L = 10$ m, and $\ln(R_e/r_w) = 3$, (11) yields $t_{90\%} = 1.82$ s. Thus if y_0 is taken as 30 cm, it takes 1.8 s for the water level to rise 27 cm, another 1.8 s for the next 2.7 cm (90% of the remaining 3 cm), and another 1.8 s for the next 0.27 cm, or a total of 5.4 s for a rise of 29.97 cm. Measurement of this fast rise requires a sensitive and accurate transducer and a fast-response recorder. The rate of rise can be reduced by allowing groundwater to enter through only a portion of the open section of the well, as can be accomplished with packers.

For a moderately permeable aquifer with, for example, $K = 1$ m/day, a well with $r_c = 0.1$ m and $L = 20$ m, and $\ln(R_e/r_w) = 5$, (11) yields $t = 11.4$ s. In this case, it would take the water level 22.8 s to rise from 30 cm to 0.3 cm below static level.

EXAMPLE

A slug test was performed on a cased well in the alluvial deposits of the Salt River bed west of Phoenix, Arizona. The well, known as the east well, is located about 20 m east of six

rapid infiltration basins for groundwater recharge with sewage effluent [Bouwer, 1970]. The static water table was at a depth of 3 m. $D = 80$ m, $H = 5.5$ m, $L = 4.56$ m, $r_c = 0.076$ m, and r_w was taken as 0.12 m to allow for development of the aquifer around the perforated portion of the casing. A Statham PM131TC pressure transducer was suspended about 1 m below the static water level in the well (when trade names and company names are included, they are for the convenience of the reader and do not imply preferential endorsement of a particular product or company over others by the U.S Department of Agriculture). A solid cylinder with a volume equivalent to a 0.32-m change in water level in the well was also placed below the water level. When the water level had returned to equilibrium, the cylinder was quickly removed. The transducer output, recorded on a Sargent millivolt recorder, yielded the y-t relationship shown in Figure 4 with y plotted on a logarithmic scale. The straight-line portion is the valid part of the readings. The actual y_0 value of 0.29 m indicated by the straight line is close to the theoretical value of 0.32 m calculated from the displacement of the submerged cylinder.

Extending the straight line in Figure 4 shows that for the arbitrarily selected t value of 20 s, $y = 0.0025$ m. Thus $(1/t) \ln y_0/y_t = 0.238$ s^{-1}. The value of $L/r_w = 38$, for which Figure 3 yields $A = 2.6$ and $B = 0.42$. Substituting these values into (8) and using the maximum value of 6 for $\ln[(D - H)/r_w]$ (since $\ln[(D - H)/r_w]$ for the well exceeds 6) yield $\ln(R_e/r_w) = 2.37$. Equation (5) then gives $K = 0.00036$ m/s $= 31$ m/day. This value agrees with K values of 10 and 53 m/day obtained previously with the tube method on two nearby observation wells [Bouwer, 1970]. These K values were essentially point measurements on the aquifer immediately around the well bottoms, which were at depths of 9.1 and 6.1 m, respectively.

COMPARISONS

Piezometer method.   The geometry to which (8) and (9) and the coefficients in Figure 3 apply overlaps the geometry of the

piezometer method at the lower values of L/r_w. With the piezometer method a cavity is augered out in the soil below a piezometer tube. The water level in the tube is abruptly lowered, and K of the soil around the cavity is calculated from the rate of rise of the water level in the tube [Bouwer and Jackson. 1974]. The equation for K is

$$K = \frac{\pi r_w^2}{A_Y} \frac{1}{t} \ln \frac{y_0}{y_t} \qquad (12)$$

where A_Y is a geometry factor with dimension of length. Values of A_Y were evaluated with an electrolytic tank analog by Young [1968], whose results were expressed in tabular form as $A_Y r_w$ for different values of L/r_w (ranging between 0 and 8), (H/r_w), and $(D - H)/r_w$.

Taking a hypothetical case where $L/r_w = 8$, $H/r_w = 12$, and $D/r_w = 16$, K calculated with (5) is 18% below K calculated with (12). This is more than the 10% error normally expected with (8) and (9) for the L/H value of 0.67 in this case. The larger discrepancy may be due to the difference in methodology, or to the fact that the L/r_w value is close to the lower limit of the range covered on the resistance network analog.

An approximate equation for calculating K with the piezometer method was presented by Hvorslev [1951]. The equation, which is based on the assumptions of an ellipsoidal cavity or well screen and infinite vertical extent (upward and downward) of the flow system, contains a term $[1 + (L/2r_w)^2]^{1/2}$. For most well-slug-test geometries. $L/2r_w$ will be sufficiently large to permit replacement of this term by $L/2r_w$. In that case, however. Hvorslev's equation for Q yields $R_e = L$, which is not true. In reality, R_e is considerably less than L. For example, if $L = 40$ m. $r_w = 0.4$ m. $H = 80$ m. and $D = \infty$, (8) shows that $R_e = 11.9$ m, which is much less than the value of 40 m indicated by Hvorslev's equation. However, since the calculation of K is based on $\ln (R_e/r_w)$ as shown by (5), the error in K is less than the error in R_e (i.e., 36 and 236%, respectively, in this case).

If, for the above example, the top of the well screen or cavity had been taken at the same level as the water table ($H = 40$ m). R_e would have been 8.6 m and Hvorslev's equation would have yielded a K value that is 50% higher than K given by (5). The larger error is probably due to Hvorslev's assumption of infinite vertical (upward) extent of the flow system, which is not met when the cavity is immediately below the water table. Using Hvorslev's equation for cavities immediately below a confining layer would increase the error to 73%, but this, of course, is due to the fact that a water table is not a solid boundary. Hvorslev's equation for the confining layer case can be shown to yield $R_e = 2L$.

Auger hole method. The analog analyses for (8) and (9) and Figure 3 were performed for $L < H$, because short circuiting between the water table and the well prevented simulation of the case where $L = H$. If the analog results are extrapolated to $L = H$, however, the geometry of the system in Figure 1 becomes similar to that of the auger hole technique, for which a number of equations and graphs have been developed to calculate K from the rise of the water level in the well [Bouwer and Jackson, 1974]. Boast and Kirkham [1971], for example, developed the equation

$$K = C_{HK} \frac{\Delta y}{\Delta t} \qquad (13)$$

where C_{HK} was determined mathematically and expressed in tabular form for various values of $L r_w$. $(D - H) r_w$, and since the rate of rise of the water level in the hole after
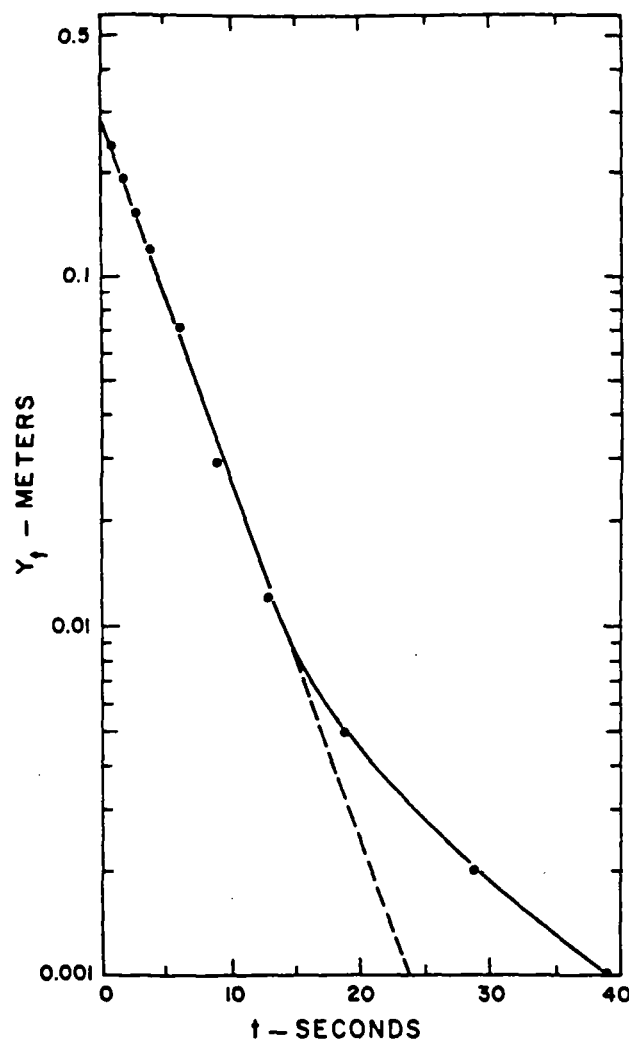

Fig. 4. Plot of y versus t for slug test on east well.

the removal of a slug of water decreases with decreasing y, $\Delta y/\Delta t$ is not a constant and the value of K obtained with this procedure depends on the magnitude of Δy used in the field measurements. The general rule is that Δy should be relatively small.

Taking a hypothetical case where $y_0 = 2.5$ m, $y_t = 2.4$ m, $\Delta t = 10$ s, $L = H = 5$ m, $D = 6$ m, and $r_w = 0.1$ m, (5) yields a K value that is 36% lower than K calculated with (13). However, if y_t is taken as 0.5 m, which should give $\Delta t = 394$ s according to the theory that $(1/t) \ln y_0/y_t$ is constant, the K value yielded by (5) is 26% higher than K obtained with (13). If y_t is taken as 0.9 m, (5) and (13) give identical results.

Slug test on wells in confined aquifers. The confined aquifer for which the slug test by Cooper et al. [1967] was developed is an aquifer with an internal water source, for example, recharge through aquitards or compression of confining layers or other material. This situation is similar to that of the unconfined aquifer presented in this paper because the water table is considered horizontal, like the upper boundary of a confined aquifer, and the water table is a plane source. Thus K or T calculated with (5) or (6) should be of the same order as K calculated with the procedure of Cooper et al. [1967], which involves plotting the rise of the water level in the well and finding the best fit on a family of type curves. Cooper et al. [1967] presented an example of the calculation of T for a well

with $r_c = r_w = 0.076$ m and $L = 98$ m. The resulting value of T was 45.8 m²/day. Values of D and H for this well were not given. However, since the well was 122 m deep and completely penetrating (at least theoretically), D and H must have been between 98 and 122 m. Assuming that both D and H were 100 m, (6) yields $T = 62.8$ m²/day, which is compatible with T obtained by Cooper et al.

CONCLUSIONS

The hydraulic conductivity of an aquifer near a well can be calculated from the rise of the water level in the well after a slug of water is suddenly removed. The calculation is based on the Thiem equation, using an effective radius R_e for the distance over which the head difference between the equilibrium water table in the aquifer and the water level in the well is dissipated. Values of R_e were evaluated by electrical resistance network analog. An empirical equation was then developed to relate R_e to the geometry of the system. This equation is accurate to within 10–25%, depending on how much of the well below the water table is perforated or otherwise open. The technique is applicable to partially or completely penetrating wells in unconfined aquifers. It can also be used to estimate the hydraulic conductivity of confined aquifers that receive water from the upper confining layer through recharge or compression.

The vertical distance between the rising water level in the well and the equilibrium water table in the aquifer must yield a straight line when it is plotted on a logarithmic scale against time. This can be used to check the validity of field measurements and to obtain the best-fitting line for calculating the hydraulic conductivity. Permeable aquifers produce rapidly rising water levels that can be measured with fast-response pressure transducers and strip chart recorders or x-y plotters. The portion of the aquifer sampled for hydraulic conductivity with the slug test is approximately a cylinder with radius R_e and a height somewhat larger than the perforated or otherwise open section of the well.

Hydraulic conductivity values obtained with the proposed slug test are compatible with those yielded by the auger hole and piezometer techniques where the geometries of the systems overlap, and by a slug test for completely penetrating wells in confined aquifers.

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ATTACHMENT 3

SUMMARY OF HAZARDOUS SUBSTANCE LIST
VOLATILE ORGANIC COMPOUNDS AND
INORGANIC COMPOUNDS

Method Detection Limits for
HSL Organics

| Volatiles | CAS Number | Detection Limits[c] | |
		Low Water[a] ug/L	Low Soil/Sediment[b] ug/Kg
1. Chloromethane	74-87-3	10	10
2. Bromomethane	74-83-9	10	10
3. Vinyl Chloride	75-01-4	10	10
4. Chloroethane	75-00-3	10	10
5. Methylene Chloride	75-09-2	5	5
6. Acetone	67-64-1	10	10
7. Carbon Disulfide	75-15-0	5	5
8. 1,1-Dichloroethene	75-35-4	5	5
9. 1,1-Dichloroethane	75-35-3	5	5
10. trans-1,2-Dichloroethene	156-60-5	5	5
11. Chloroform	67-66-3	5	5
12. 1,2-Dichloroethane	107-06-2	5	5
13. 2-Butanone	78-93-3	10	10
14. 1,1,1-Trichloroethane	71-55-6	5	5
15. Carbon Tetrachloride	56-23-5	5	5
16. Vinyl Acetate	108-05-4	10	10
17. Bromodichloromethane	75-27-4	5	5
18. 1,1,2,2-Tetrachloroethane	79-34-5	5	5
19. 1,2-Dichloropropane	78-87-5	5	5
20. trans-1,3-Dichloropropene	10061-02-6	5	5
21. Trichloroethene	79-01-6	5	5
22. Dibromochloromethane	124-48-1	5	5
23. 1,1,2-Trichloroethane	79-00-5	5	5
24. Benzene	71-43-2	5	5
25. cis-1,3-Dichloropropene	10061-01-5	5	5

| | | Detection Limits[a] | |
| | | Low Water[a] | Low Soil/Sediment[b] |
Volatiles	CAS Number	ug/L	ug/Kg
26. 2-Chloroethyl Vinyl Ether	110-75-8	10	10
27. Bromoform	75-25-2	5	5
28. 2-Hexanone	591-78-6	10	10
29. 4-Methyl-2-pentanone	108-10-1	10	10
30. Tetrachloroethene	127-18-4	5	5
31. Toluene	108-88-3	5	5
32. Chlorobenzene	108-90-7	5	5
33. Ethyl Benzene	100-41-4	5	5
34. Styrene	100-42-5	5	5
35. Total Xylenes		5	5

[a] Medium Water Contract Required Detection Limits (CRDL) for Volatile HSL Compounds are 100 times the individual Low Water CRDL.

[b] Medium Soil/Sediment Contract Required Detection Limits (CRDL) for Volatile HSL Compounds are 100 times the individual Low Soil/Sediment CRDL.

Element	Contract Required Detection Level[1,2] (ug/L)
Aluminum	200
Antimony	60
Arsenic	10
Barium	200
Beryllium	5
Cadmium	5
Calcium	5000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Lead	5
Magnesium	5000
Manganese	15
Mercury	0.2
Nickel	40
Potassium	5000
Selenium	5
Silver	10
Sodium	5000
Thallium	10
Vanadium	50
Zinc	20
Cyanide	10

1: Any analytical method specified in SOW Exhibit D may be utilized as long as the documented instrument or method detection limits meet the Contract Required Detection Level (CRDL) requirements. Higher detection levels may only be used in the following circumstance:

If the sample concentration exceeds two times the detection limit of the instrument or method in use, the value may be reported even though the instrument or method detection limit may not equal the contract required detection level. This is illustrated in the example below:

For lead:
Method in use = ICP
Instrument Detection Limit (IDL) = 40
Sample concentration = 85
Contract Required Detection Level (CRDL) = 5

The value of 85 may be reported even though instrument detection limit is greater than required detection level. The instrument or method detection limit must be documented as described in Exhibit E.

2: These CRDL are the instrument detection limits obtained in pure water that must be met using the procedure in Exhibit E. The detection limits for samples may be considerably higher depending on the sample matrix.